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The Consortium

Cooperation versus Competition

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This study analyzes the trend toward increasing numbers and types of industrial cooperative ventures - consortia. The patterns of industrial cooperation are identified and case studies of five R&D consortia are presented. Government's role in encouraging and supporting consortia is discussed in the context of domestic competition and the international competitiveness of American firms.

We conclude that the antitrust laws should be revised with caveats to permit joint production and that Government financial assistance to consortia should be generally limited to broad measures (such as tax incentives) rather than industry-specific or company-specific grants.

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LMI

Executive Summary

THE CONSORTIUM
COOPERATION VERSUS COMPETITION

United States economic policy has long held that unfettered domestic marketplace competition among the greatest number of independent producers is ideal. That policy leads to the belief that cooperation among otherwise independent producers is bad – or at best suspect. Competition, in conjunction with the basic principles of free enterprise, open markets, and minimal Government intrusion, has served the American economy well.

Few would disagree, however, that the environment facing American manufacturers has changed substantially since the turn of the century when the antitrust laws (principally the Sherman and Clayton Acts) first formalized the preference for competition. Although the United States has always been a trading nation, competition historically has been defined in the context of domestic producers in the domestic marketplace. Measures of competition, such as producer concentration, have not traditionally recognized the presence of foreign producers in a global marketplace. Today's marketplace is global. Japan has emerged as an economic rival to the United States, and Europe is poised to do so as well. Foreign firms have captured a solid share of U.S. domestic markets in electronics, automobiles, machine tools, and many other industries. The cost of developing new manufacturing technology is increasing in step with the accelerating pace of technological change. More than ever, companies must turn to innovative product designs, materials, and processes to remain competitive, but the technologies for those innovations are often beyond the financial reach of individual firms, and even when they are affordable, the risk of technical failure or early obsolescence is high.

In this new environment, companies are increasingly forming consortia and other cooperative ventures. We define the consortium as an activity supported by more than one firm and aimed at developing, producing, or marketing a new product, a new process, or a new management technique that benefits the consortium's members simultaneously and exclusively. We exclude injurious forms of interfirm

cooperation, such as price collusion, and we also exclude publicly funded R&D where access to the results is unlimited. Cooperative ventures perform many activities from R&D through production to marketing and distribution. Of the more than 100 R&D ventures that have formed since 1984, we examined five in detail. We found that although the environment seems ripe for cooperative activity, the success of many consortia is yet to be proved. Also, while we expected that small firms would take advantage of the leveraging effects of cooperation, we observed that, for the most part, consortia are formed by large companies. Small companies tend to guard jealously the product or process niche that offers them growth and prosperity. This wariness of consortia is often heightened by a fear of antitrust, a lack of awareness of the potential benefits to cooperation, and a lack of expertise in organizing and managing cooperative ventures.

A consortium is, in theory, detrimental to competition. Firms left outside the venture will be denied access to new products or processes, increasing the market power of the consortium members at the expense of nonmembers. The original antitrust laws, the Sherman and Clayton Acts, applied the policies and tests of acceptability for mergers and acquisitions to consortia. There are three exceptional situations, however, where a consortium is not anticompetitive. In these situations, the cooperation takes place in or indeed is warranted by a market which deviates from the competitive ideal.

A consortium is warranted when the resources required for an undertaking are large and indivisible. Certain undertakings by a firm, notably R&D, require large, lump-sum investments, particularly at the early stages when risks and uncertainties are high. The expected gains may be great, but they are also accompanied by a significant probability of failure and attendant large losses. In this case, where the risk-averse behavior of investors also tends to limit financial resources, a number of economically viable R&D activities probably would not be implemented in a purely competitive economic system. With the passage of the National Cooperative Research Act of 1984, the Government now sanctions joint R&D provided the participants apply the results separately in independent production and sales.

A consortium is also justifiable when domestic firms face large, integrated foreign firms operating under contrasting economic policies that include various forms of government support. Markets are becoming increasingly global and some foreign firms may exhibit noncompetitive behavior by U.S. standards. For example,

foreign firms may resort to predatory pricing with the objective of eliminating rivals in the U.S. market. There are domestic legal remedies to predatory pricing, but they are often applied after-the-fact and have little effect on overseas markets. A more concentrated U.S. market may be the only practical solution to predatory pricing. In such instances, it might be preferable, from a national welfare point of view, to allow a few American oligopolies to dominate a well-defined industry rather than letting it be taken over by fewer international oligopolies.

Trade restrictions are sometimes erected to protect a domestic industry that has become complacent and is losing market share to foreign firms. Foreign firms have used joint ventures to establish assembly operations in the United States in order to overcome trade restrictions. International ventures that bypass these protectionist barriers generally enhance competition.

The main public policy issue regarding consortia is the degree to which the Government should allow industrial cooperation and impose controls on the formation of consortia. A secondary issue is the extent to which the Government should provide financial support to consortia.

We believe that further revision of the antitrust laws would be beneficial. The large, indivisible investments in R&D recognized by the National Cooperative Research Act are also incurred in building and equipping modern production facilities. Also, because it is difficult to influence other nations' economic policies (an approach that was tried and proved to be ineffective during the 1980s), there are circumstances where domestic producers' losses can be controlled and reversed only by deviating from the paradigm of pure competition.

The antitrust laws should therefore be revised to permit joint production in certain circumstances. Joint production ventures should be subject to market concentration restrictions to protect nonparticipating producers and consumers from collusion. Concentration should be redefined to include the global market. Several bills have been submitted to the Congress with these provisions.

We favor general measures of Government financial support of consortia rather than financial support for specific industries or companies. Specific actions tend to reward consortia with the strongest lobbies rather than those with the greatest expected national benefit and should be avoided. General measures usually are implemented through tax policy. Tax incentives for research and capital investment,

coupled with revised antitrust laws, could stimulate consortia within U.S. industries and allow them to compete with foreign firms for market share without damaging domestic competition. We also recommend that the Government, through state and local agencies, sponsor education programs in the antitrust, tax, organizational, and property rights implications of cooperative ventures in order to facilitate increased small business participation in consortia.

The original antitrust laws were intended to control the injurious effect of mergers and acquisitions on market competition. They are not equally applicable to other, more benign forms of industrial cooperation. The Government has already recognized this proposition by permitting cooperative R&D. The outstanding questions that the Government now faces are how much further to liberalize the antitrust laws and what, if any, financial incentives to provide to the private sector in promoting cooperative action. The solutions to these questions will involve trade-offs. Economically viable competitors can be maintained in the global marketplace at the expense of increased domestic producer concentration. The instances cited above – large investment projects, unfair foreign competition, and protectionist trade barriers – are certainly situations where the Government should encourage cooperation by allowing joint production and providing broad financial incentives.

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CHAPTER 1

INTRODUCTION

BACKGROUND

The business environment facing American manufacturing companies is clearly changing. Many U.S. industries are losing domestic and global market share to foreign competitors. For example, the American machine tool industry's share of the domestic market, in terms of dollars, declined from 95 percent in 1965 to 51 percent in 1987, primarily to the benefit of Japanese and West German producers.[1] The American merchant semiconductor industry has seen its global market share, which includes products made abroad by American-owned companies, decline from about 60 percent in 1975 to less than 40 percent today.[2] In one semiconductor product line, dynamic random access memories (DRAMs), American merchant producers making DRAMs for resale have been virtually eliminated by Japanese companies.[3]

Other factors characterize the changing business environment. The increasing use of automation in product design, process design, and production operations increases fixed and semi-fixed costs relative to variable costs, which can limit market entry and raise production break-even points. High technology also requires a more highly educated work force. Finally, U.S. markets are freer today than they were 30 years ago. The ratio of import duties to the value of imports to the United States has declined from 7 percent in 1960 to 3 percent in 1987.[4]

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[1] *1988–89 Economic Handbook of the Machine Tool Industry*. McLean, Va.: NMTBA, The Association for Manufacturing Technology, 1988, p. 127.

[2] *Semiconductor Industry Association Yearbook and Directory, 1988*. Cupertino, Calif.: Semiconductor Industry Association, 1987, p. 24. Statistics do not include captive semiconductor producers who make semiconductors for their own consumption.

[3] For a discussion of the plight of other American industries, see Dertouzos, Michael L., Richard K. Lester, and Robert M. Solow. *Made in America: Regaining the Competitive Edge*. Cambridge, Mass.: the MIT Press, 1989.

[4] U.S. Department of Commerce, Bureau of the Census. *Statistical Abstract of the United States: 1989*. (109th Edition), p. 796.

As a result of these changes to the manufacturing environment, many industry and Government leaders are advocating actions to improve U.S. industrial competitiveness. Industrial competitiveness, broadly defined, is the ability of manufacturing companies to maintain or expand market share at home and abroad by selling efficiently-produced, innovative, high-quality products. American industrial competitiveness is the foundation of our economic and military security. Our manufacturing base must compete aggressively in domestic and foreign markets if our standard of living is to be sustained and improved.

As one response to the need for greater competitiveness, many companies are entering cooperative ventures with suppliers, equipment makers, customers, and in some cases, even competitors. The purpose of these efforts is to improve product and process technologies and to improve the flow of goods and services in such areas as inventory control, order processing, distribution, and transportation. American economic policy has long held that cooperative ventures, particularly those among competitors, diminish competition and are thus suspect. The antitrust laws, almost a century old, have historically applied the tests of acceptability for mergers and acquisitions to all forms of industrial cooperation. These laws have generally inhibited less extreme and possibly procompetitive forms of cooperation.

We see clear evidence that Congress and the executive branch have recognized the changing industrial environment. The National Cooperative Research Act of 1984 (NCRA), for example, allows American companies to form cooperative ventures for R&D. However, it does not permit cooperative production, pricing, and other activities subsequent to R&D. Over 245 registrations, representing about 100 separate ventures, have been filed with the Government (as provided for in the Act).

OBJECTIVES

In view of changes facing the American manufacturing sector and their implications for the defense industrial base, we have examined the current trend toward increasing formation of cooperative ventures among American companies. In general, we sought to assess the role of consortia in enhancing the American manufacturing sector's competitiveness. In particular, we sought the answers to, or

insight into, the following questions:

- Have cooperative ventures satisfied the objectives of the participants?
- Do cooperative ventures enhance competition in the domestic marketplace?
- Do cooperative ventures enhance the overall competitiveness of domestic industries in the world marketplace?
- Should the Federal Government enact policies favorable to certain types of cooperative ventures or contribute directly to particular ventures?

Consortia are often poorly defined and narrowly perceived as being applicable to only high-technology ventures. Discussions of the Government's role in supporting consortia are also often limited to a single issue, such as direct Government funding or revisions to antitrust policy. In reality, all types of industries form consortia for myriad purposes and under the influence of a wide range of laws and public policies.

SCOPE

We define the consortium as an activity supported by more than one independent firm and aimed at developing, producing, or marketing a new product, a new process, or a new management technique that benefits the consortium's members simultaneously and exclusively. This broad definition includes cooperation ranging from informal to complex and from short term to long term. We exclude, however, injurious forms of interfirm cooperation, such as price collusion and we also exclude publicly funded R&D where access to the results is unlimited.

By our definition, consortia, strategic alliances, joint ventures, and other commonly used terms all refer to forms of cooperative venture, and we shall use those terms interchangeably. Where it is necessary to distinguish among types of cooperative ventures, we present terminology to do so.

The focus of our study is on industrial consortia. We have not examined joint ventures among industry, academia, and Government, unless these ventures involved direct cooperation between two or more private companies. We do not imply that the excluded ventures are unimportant; rather, we wish to focus our research on the competitive effects of "industry-with-industry" cooperation.

REPORT ORGANIZATION

In Chapter 2, we present a summary of our findings and our conclusions. The remainder of the report expands on the ideas presented there. In Chapter 3, we describe the factors that motivate companies to form consortia, the activities consortia perform, and the most common organizational structures for consortia. Chapter 4 reviews the laws and Government policies that affect consortia in the areas of antitrust, Government acquisition, direct Government funding, tax, and trade. Appendix A provides some examples of recent cooperative ventures. In Appendix B we present case studies of five of these ventures from the metalworking and semiconductor industries. Finally, in Appendix C we list those ventures that have registered with the Government under the NCRA.

CHAPTER 2

SUMMARY AND CONCLUSIONS

PATTERNS OF INDUSTRIAL COOPERATION

The variety in the functions and forms of cooperative ventures is enormous, even within the scope of industrial cooperation that we described in Chapter 1. Appendix A lists some of the ventures we have reviewed. We classify those ventures on the basis of their objectives, the activities they have undertaken, their organizational structures, and some of their other characteristics.

Cooperative ventures are generally undertaken for one or more of the following reasons:

- To share costs and risks
- To respond to global competition
- To access new products, technology, and expertise
- To streamline relations with suppliers and customers.

In principle, a consortium's activities can cover any stage of the industrial process from R&D through production to marketing and distribution. We broadly classify these activities as preproduction, production, and postproduction, respectively.

Preproduction consortia typically perform R&D. In these ventures, pursuant to the NCRA, companies first share the expense of R&D and then compete in production and marketing. Appendix B presents five case studies of these consortia from the metalworking/machine tool and semiconductor industries. Such R&D consortia tend to form in high-technology industries that are subject to high import penetration. This type of cooperation can create technologies and capabilities for individual firms that would otherwise be unavailable to them. Curiously, U.S. companies, while fearing a loss of technological leadership to foreign firms, continue to enter into international technology-sharing joint ventures.

Production and postproduction ventures perform manufacturing, distribution, marketing, and related activities. Such ventures are often formed in industries with import restrictions, as foreign firms enter joint ventures or minority interests with domestic firms. In these cases, joint ventures introduce more competitors into the marketplace and offset the generally anticompetitive nature of the trade restrictions.

Most consortia are organized as either equity ventures or contractual ventures although other forms are possible. In an equity venture, two or more firms contribute equity to a new, separate organization. Companies favor such an organization for long-term projects whose scopes are relatively broad. A contractual venture is formed when two or more firms formally cooperate but create no separate entity. Industry uses this approach for shorter term efforts, such as developing a specific product or sharing a particular technology. Other organizational approaches – informal alliances and minority holdings, for example – are sometimes used for cooperative purposes.

We also describe consortia by their scope and the size and relationship of the participants. "Strategic" ventures have broad goals and operate for an indefinite period. "Tactical" ventures have relatively narrow goals and exist for the duration of a single project.

Based on the objectives of cooperative ventures listed above, we would expect small companies to take advantage of the leveraging effects of consortia. Yet we find that most consortia are formed by large companies, not small firms. Research indicates that small companies are wary of consortia because of their independent spirit, fear of antitrust laws, lack of awareness of the potential benefits, and lack of requisite specialized expertise. The Government might encourage small firm participation in consortia by assisting in providing the required expertise.

The terms "vertical" and "horizontal" describe the relationship of participants in a venture. A vertical relationship exists when cooperation involves suppliers and customers working for mutual improvement; a horizontal relationship exists when the activities are among companies who are otherwise competitors. Vertically oriented ventures are usually informal or contractual, reflecting the natural extension to traditional "arm's length" business interaction. Horizontal ventures are usually structured as equity ventures, particularly if they are strategic.

LAWS AND PUBLIC POLICIES AFFECTING CONSORTIA

The laws and public policies that affect consortia include antitrust laws, Government acquisition strategies, direct Government funding, indirect financial support via tax incentives, and trade policies. The Sherman Act, Clayton Act, and other basic antitrust laws have traditionally prohibited horizontal industrial cooperation by imposing restrictions punishable by severe penalties. As previously mentioned, the NCRA encourages preproduction consortia, requiring only that the consortia file a notice of their activities with the Government. A list of NCRA registrants appears in Appendix C.

Congress is now considering at least three different bills that would allow even greater latitude for business cooperation. These bills would permit cooperative activities to include joint production and marketing. They differ primarily in the level of Government approval and the degree of antitrust relief provided. The most permissive of the bills would grant total antitrust immunity for consortia making defense products. Another bill would grant limited immunity (actual damages rather than treble damages) to consortia that register with the Government. The third bill would also grant limited immunity, but ventures would be subject to explicit Government review and approval. While each of these bills would encourage consortia by reducing the threat of antitrust penalties, we cannot anticipate the number of consortia that would be formed, particularly among small businesses, were one of the bills to become law.

Special examples of cooperative arrangements to enhance competition occur when the Government itself acquires major weapon systems. The Government is often the single buyer of these systems and thus initiates and funds their design. Instead of dealing with a single producer who has won a design competition, the Government often creates secondary production sources. Government acquisition techniques such as "leader-follower" and "contractor teaming" use cooperative ventures during a weapon system's development phase to introduce competition during the production phase. These strategies have had mixed success. The leader-follower approach has produced competition but, so far, contractor teaming has not. Also, when contractors cooperate on one weapon system but compete or expect to compete on another, similar system, they may not share their best technology in the cooperative venture.

In some instances, the Government provides direct financial support to consortia. For example, SEMATECH (SEmiconductor MAnufacturing TECHnology),

a consortium of 14 U.S. semiconductor manufacturers, receives $100 million a year from the Federal Government. Proponents of direct funding argue that such support reduces business risk and allows U.S. companies to compete in new, high-technology product markets. Direct Government funding of consortia, however, is likely to be limited by a lack of funds and the general aversion to public investment in activities in which most of the apparent benefits are private.

U.S. tax policy does not now differentiate consortia from noncooperating businesses. Tax incentives to encourage consortia in critical industries could serve as a broad-based catalyst. Incentives might include tax credits for investment and research, and accelerated depreciation allowances. Such support might be more efficient and equitable than the direct Government funding of specific consortia. To date, however, we know of no action or proposals of this type.

Trade restrictions, such as tariffs and import quotas, are usually intended to "protect" a specific domestic industry. A large body of opinion opposes protection since it is generally held that protection hurts domestic consumers more than it helps protected producers. Thus, protection should be probably confined to critical defense sectors where factors beyond private benefits and costs play a decisive role.

Protection sometimes encourages foreign manufacturers to form joint ventures with American firms in order to establish operations in America. These ventures foster competition. The domestic marketplace gains competition because the foreign firms maintain a presence, otherwise reduced, via the joint venture. The ventures, in effect, "jump" the barrier of the trade restrictions.

We recognize, however, that not all ventures between domestic and foreign firms increase competition. Some trade restrictions are imposed to punish foreign firms for "unfair" practices such as dumping and receiving Government subsidies. Ventures that are used to bypass punitive trade restrictions diminish the effect of those barriers to the detriment of "fair" competition.

We divide the laws and public policies affecting consortia into general actions and specific actions. General actions affect all businesses more or less equally; they do not target a particular sector or industry. Antitrust law and tax policies are primarily general actions. Specific actions focus on a given sector, industry, or business. Government acquisition strategies are program-specific. Direct financial assistance and trade policy are almost always industry-specific.

COOPERATION VERSUS COMPETITION

We now return to our study objectives and, from our observations, draw conclusions about the role of consortia in enhancing American industrial competitiveness.

Have cooperative ventures satisfied the objectives of the participants?

We are not able to answer this question definitively. Many cooperative ventures, such as the R&D consortia we studied, have yet to meet the objectives of the participating companies. Ventures such as SEMATECH are making technical progress but have yet to produce improved market shares for American manufacturers. Furthermore, when the goals of a venture are broad (such as, "improve manufacturing competitiveness"), specific venture activities or successes cannot readily be linked to changes in aggregate industry performance.

Do cooperative ventures enhance competition in the domestic marketplace?

Cooperation does not always enhance competition but neither does it necessarily diminish it. We have observed situations in which cooperation has enhanced domestic marketplace competition by introducing more firms and better products into the marketplace. Companies that cooperate to develop technologies can use those technologies to market competing products. When several companies pool R&D expenses and share technology rights, the resulting competition can be greater than if only one company were to have access to the technology. However, we observe that most consortium members are large companies with individual annual sales over $10 billion in the case of semiconductor consortia. The ill-fated semiconductor consortium, U.S. Memories, was dominated by IBM, Digital Equipment Corporation, and Hewlett-Packard and had only one member, LSI Logic, with annual sales less than $1 billion. Cooperation, if only limited to, or practiced by, large companies, will not enhance the competitive position of small U.S. businesses. It appears that some additional catalyst is needed to promote cooperation among small businesses. We recommend that the Government facilitate consortia among small businesses by sponsoring education programs and information packages. These services could advise small businesses of the antitrust, tax, organizational, and property rights issues that pertain to industrial cooperation. The information could be provided at relatively little cost through the Industrial Extension System or other existing Federal or state agencies.

Do cooperative ventures enhance the overall competitiveness of domestic industries in the world marketplace?

The primary goal of several of the consortia we examined is to enhance American firms' global competitiveness. It is simply too early in the development of these consortia to evaluate their success toward that goal. Conceptually, however, we expect that cooperative ventures will enhance the global competitiveness of U.S. firms as domestic firms draw from each other the resources they need to develop, produce, and distribute world-class products. American firms use international joint ventures to penetrate foreign markets, and foreign firms do likewise in the American market.

Should the Federal Government enact policies favorable to certain types of cooperative ventures or contribute directly to particular ventures?

The Government could support cooperative ventures through a broad range of actions. We favor general actions over industry-specific ones. The major policy issue relates to antitrust law. Government must decide how far to go in legitimizing cooperative activity that is beyond R&D but short of merger and acquisition. For example, the Government could legalize joint production but not joint distribution and sales. As another alternative, the Government could allow all forms of cooperative activity but require registration as it does in the NCRA or it could require a review and approval process based on clear criteria that it will develop. The criteria should include measures of market share and concentration and should recognize that the markets are now global rather than merely domestic.

We have observed that all cooperative ventures are not necessarily anticompetitive. We believe that some antitrust liberalization would be beneficial because we are currently subjecting some benign forms of cooperation, such as joint investment in and operation of specialized manufacturing facilities, to the same restrictions applied to mergers and acquisitions. At the same time, the Government must still guard against collusive behavior because not all cooperation enhances competition. In combination with antitrust revisions, the Government can provide further encouragement to consortia through broad tax incentives. Government should avoid the direct targeting of specific consortia, except in clearly demonstrated cases of national security risk.

CHAPTER 3

PATTERNS OF INDUSTRIAL COOPERATION

INTRODUCTION

Cooperative ventures serve many functions and take many forms, even within the scope of industrial cooperation as defined in this report. Industrial and public leaders are responding to changes in the competitive environment in part by contemplating and evaluating consortia. If those leaders are able to distinguish between the different kinds of cooperative ventures and understand why and how they are formed, they are more likely to be successful in improving industrial competitiveness.

This chapter describes the motives for industrial cooperation, the activities undertaken by consortia, and the ways in which consortia are commonly structured. The chapter concludes by presenting examples of cooperative ventures from industry and discussing measures of success.

MOTIVES FOR COOPERATION

Sharing Costs and Risks

Perhaps the most common motive for industrial cooperation is the need to share the costs and risks of a new effort. Initiatives in R&D, engineering, and manufacturing require a "critical mass" of funds to cover up-front, fixed costs. The costs of technology and automation are rising, both absolutely and in relation to the variable costs of direct labor and materials. For example, IBM estimates that it will spend over $800 million to develop X-ray lithography, a new process for fabricating semiconductor wafers.[1]

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[1]"Innovation in America." *Business Week*. (16 Jun 1989): p. 17.

The development of new products and processes often carries a high risk of failure because of technological or market uncertainties. Consortia enable companies to reduce individually their potential for financial ruin.[2] They enable companies to invest in a greater number of projects for the same amount of money. This diversification across a greater number of high-risk, high-reward projects diminishes the total risk of innovation spending. The National Center for Manufacturing Sciences (NCMS) was established to benefit the small companies of the machine tool industry, who could benefit greatly from leveraged research. The NCMS conducts research in manufacturing processes, an area that many American companies have neglected in favor of product development and marketing.

Responding to Global Markets and Competition

Industrial markets and competition are global. U.S. companies, at home and abroad, face foreign competition that has taken the lead in producing innovative, high-quality, and low-cost items in many industries. Foreign firms' success may be the result of cooperation, industry integration, and government support to a degree greater than in the United States. American companies sometimes form consortia in an attempt to emulate the strengths of such relationships, while maintaining the traditional independence of American industry. A consortium called the Microelectronics and Computer Technology Corporation (MCC), for example, was initially formed in response to Japanese cooperative research on a "fifth-generation" supercomputer.

The semiconductor and machine tool industries provide two examples of American industries facing tough foreign competition. In semiconductors, the U.S. companies' share of the world DRAM market has plummeted from 90 percent in 1975 to less than 20 percent in 1988. During the same time, the Japanese companies' share of the world market for all semiconductor devices has grown from 28 percent to 50 percent. In response, the semiconductor industry has formed at least three consortia: MCC, the Semiconductor Research Corporation (SRC), and SEMATECH.

In 1970, the American machine tool industry had a 90 percent share of the U.S. market and a 19 percent share of the world market. American machine tools now

[2]Sharing research costs usually means sharing proprietary rights to the results and, hence, the profits. This can sometimes be a drawback in seeking cooperation, especially for design firms that rely on technology developments for most of their revenues.

account for 51 percent of the domestic market and only 8 percent of the world market, on a dollar basis. Two R&D consortia, Computer Aided Manufacturing – International (CAM-I) and the NCMS, have been formed to improve the plight of the machine tool and related metalworking industries.[3]

The quest for expanding exports also impels cooperation. Three large, competitive markets are emerging: the United States, Japan, and Europe. "You can no longer be a company relying on a home market for your business with only an opportunistic approach toward exporting; rather, you have to be a global company which is operating from inside each of these three major world markets."[4] Few companies can serve all of these markets well on their own. International cooperative ventures can help a company overcome unfamiliar regulations, languages, and cultures, as well as the logistics problems of conducting business over long distances.

Many foreign governments encourage or even require that U.S. firms operating in their countries form joint ventures with local companies. That policy is prevalent in less-developed and newly industrialized countries. By forming joint ventures with local firms, U.S. companies gain access to local markets and, through the ventures, may qualify for low interest loans, loan guarantees, tax breaks, and other subsidies from foreign governments. In 1988, one-third of foreign investments by U.S. manufacturers were through joint ventures.[5]

Similarly, foreign firms sometimes use international joint ventures to enter the U.S. market. Toyota builds cars in California in a joint venture with General Motors called New United Motor Manufacturing, Inc. (NUMMI). Toyota and other Japanese auto makers circumvent U.S. import quotas (technically called "voluntary restraint agreements") by establishing joint ventures with American automakers and by locating wholly owned facilities in the United States. Thus, while the trade restrictions at first appear to restrict competition by limiting foreign imports, they

[3]Semiconductor and machine tool/metalworking consortia are discussed in more detail in Appendix B.

[4]Robert Collins, President of GE Fanuc Automation North America, Inc., as quoted in Weimer, George et al. "Strategic Alliances Make Marketing and Manufacturing an International Game." *Computer-Aided Engineering* (Nov 1988): p. IM24.

[5]*Business Finance*. Vol. 4, No. 4 (Jul/Aug 1989): p. 2.

may actually enhance competition by "forcing" foreign companies to produce domestically.[6]

Accessing Products, Technology, and Knowledge

Many of today's products rely on so many technologies that individual companies cannot maintain expertise in all of them. The need to access products, technology, and expertise is therefore a motive for industrial cooperation. A small company developing a vision system, for example, might pair with a large producer of material handling systems. The small company would access an end-product for its vision system, and the larger company would benefit by adding "intelligence" to its product. These arrangements involve greater cooperation than traditional business transactions because of the need for systems integration and engineering codevelopment. Companies also enter joint ventures to access manufacturing expertise or sales and distribution channels. General Motors' venture with Toyota, NUMMI, is providing General Motors with first-hand access to Japanese manufacturing management practices. Meanwhile, Toyota gains experience and knowledge of suppliers and workers in the United States.

The SRC, a consortium of 28 semiconductor firms, was formed to create as well as access knowledge. The SRC was formed in response to decreasing levels of university research in silicon-based semiconductor technology that had resulted in a drop in suitably trained scientists.

Streamlining the Value-Added Chain

The value-added chain comprises the various steps that a product follows from raw material to final consumption (Figure 3-1). Under traditional business practices, companies transact (buy and sell) at "arm's length" throughout the chain; suppliers and customers have little interest in each other's internal efficiencies. The Massachusetts Institute of Technology (MIT) Commission on Industrial Productivity concluded that American firms often neglect vertical relationships and thereby miss opportunities to improve the time-to-market of new products and the quality and

[6]These ventures also have other effects. American jobs are created, but ultimately capital may be lost if profits revert to overseas. Today, it is nearly impossible to define what is an American product or even what is an American company.

service of existing ones.[7] Progressive companies, however, cooperate with their suppliers and customers and realize that their collective success depends on the effectiveness of the entire value-added chain.

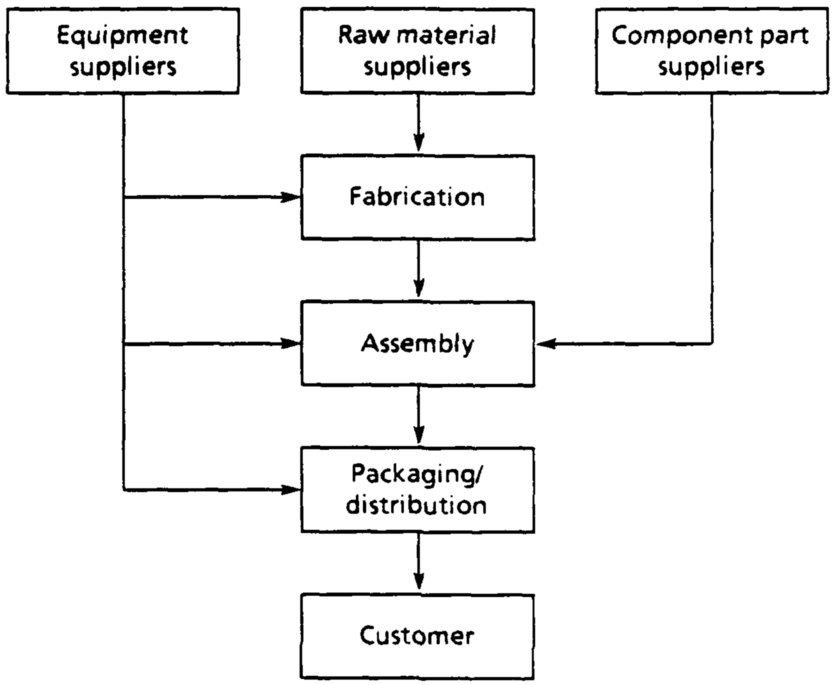

FIG. 3-1. THE VALUE-ADDED CHAIN

A set of companies that work closely together to improve the flow of goods and services along their value-added chain is called a value-adding partnership (VAP).[8] VAPs offer some of the benefits of vertical integration (merger or acquisition) yet preserve the independence of the member companies. Members of a VAP must become familiar with each other's technology and operations and commit to sharing technology and knowledge for mutual benefit.

The McKesson Corporation, a distributor of drugs, health care products, and consumer goods with annual sales of $6.7 billion, has formed a VAP with independent retailers to boost its competitiveness against large, vertically-integrated drug store chains. McKesson uses its market data to help its customers (drug stores)

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[7]Dertouzos, Michael L., op. cit., p. 100.

[8]Johnston, Russell and Paul R. Lawrence. "Beyond Vertical Integration – The Rise of the Value-Adding Partnership." *Harvard Business Review*. (Jul – Aug 1988) pp. 94 – 104

set prices and design store layouts. It also uses its computer systems to help the stores process insurance claims for prescription reimbursement. McKesson has instituted computer-to-computer ordering with its suppliers, streamlining its own replenishment operations. VAPs such as McKesson's are not expensive to establish, and they can yield substantial benefits for relatively little cost.

ACTIVITIES OF CONSORTIA

Theoretically, any business function can become a consortium activity. A consortium's activities usually follow directly from the factors that motivate the venture. We present three categories into which the major consortium activities may be placed: preproduction, production, and postproduction. The classification is somewhat arbitrary, and some ventures perform functions that cross classification boundaries. Although not perfect, this approach does provide a straightforward means of describing the activities of consortia.

Preproduction Activities

Consortia that perform product R&D, process R&D, engineering design, manufacturing process planning, or a combination of those activities are preproduction ventures. R&D ventures have become popular in the 1980s because of the expense involved in R&D and because such ventures recently received favorable treatment under the antitrust laws.

Preproduction consortia in the semiconductor industry include

- MCC
- SRC
- SEMATECH.

MCC is a consortium performing research on computer architecture, computer-aided design (CAD), packaging/interconnecting, supercomputers, and software. The SRC oversees university research, emphasizing product-related research. SEMATECH performs R&D of semiconductor manufacturing processes. We present case studies of these and other R&D consortia in Appendix B.

Preproduction ventures are typically found in high-technology industries with a substantial amount of global competition or import penetration. Semiconductors, for example, are the technology drivers for many consumer and defense products, and, as

discussed above, foreign competition is fierce. At the same time, American semiconductor companies continue to enter technology sharing cooperative agreements with foreign companies. Motorola (a member of MCC, SRC, and SEMATECH) cooperates with T...ib ınd Texas Instruments (a member of SRC and SEMATECH) is working with Hitachi. Advocates of these ventures say that U.S. companies benefit by trading American product technology for Japanese process technology. Critics charge that American companies are "giving away" their competitive stronghold – innovative designs – that foreign firms (in this case Japanese) can copy and enhance on their own.

Production Activities

Companies can cooperate in production, including the subfunctions of procurement, fabrication, and assembly.[9] Sometimes production cooperation is limited to the procurement function. Procurement cooperation takes place between suppliers and customers, who can work together to improve quality and delivery response. Dow Chemical, through its "Supplier Partnerships," evaluates vendors and seeks "mutual quality improvement" with them. Hoechst Celanese works with its customers to reduce the amount of testing the customers must do when they take delivery of Hoechst's products.[10]

Other production ventures perform the full range of procurement, fabrication, and assembly. As we mentioned above, General Motors and Toyota have formed NUMMI to jointly produce automobiles. The other major U.S. automakers, Ford and Chrysler, have similar arrangements with Japanese auto companies. If those ventures prove successful, the result should be greater competition among the U.S. firms and a narrowing of the gap between Japanese and American automobile cost and quality.

Production ventures are not new. In 1979, well before the NCRA, the Federal Trade Commission recorded 38 manufacturing joint ventures. Since Federal Trade

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[9]Some readers might classify procurement as a preproduction function. We feel the degree of interaction among purchasing, fabrication, and assembly, particularly under just-in-time inventory systems, makes our definition preferable.

[10]Goldbaum, Ellen. "New Alliances Share the Work and the Rewards." *Chemical Week* (7 Dec 1988): p. 36.

Commission data collection stopped in 1980, we do not have summary data after that time.

Postproduction Activities

Distribution, marketing, and sales are postproduction activities. Firms may join forces to share warehouse facilities or to take advantage of volume transportation discounts. For example, Abbott Laboratories and 3M have combined their order entry and distribution functions for hospital products. Many international ventures employ the expertise of the local partner to open markets that operate with different cultures and regulations. Ford has solicited the help of Mazda in exporting the Ford *Probe* and *Taurus* automobiles to Japan.

THE STRUCTURE OF CONSORTIA

Industry structures its alliances in many ways. The types of cooperative organizations fill a spectrum, bounded on one end by complete independence (no cooperation) and on the other by merger or acquisition (total, institutional cooperation). Cooperative efforts involving the least interaction are informal, noncontractual agreements. Customer-supplier cooperation often takes this form and is simply an extension of normal business activities. Informal consortia are distinguished by special efforts to improve products or operations, in contrast to the normal "arm's length" trade of goods and services.

Another way of structuring an industrial alliance is the minority holding, which occurs when one company buys a minority interest of another company's stock. The companies retain independence, yet their success is financially linked. One example comes from the automotive industry: Ford owns 25 percent of Mazda; the companies cooperate on such tasks as developing a replacement for the *Escort* and producing the *Probe*. Minority holdings are not commonly perceived as cooperative ventures because the parties are not necessarily obligated to interact. The degree of cooperation varies, depending on the businesses involved and the extent of the minority interest.

Contractual ventures represent a higher degree of cooperative interaction. Two or more firms form a contractual venture when they agree in writing to cooperate, but they do not form a new entity. Companies typically use this approach to perform a single task over a relatively short period of time. For example, a material-handling

company, a machine tool company, and a computer company may join forces to develop a manufacturing cell control unit.

Companies form an equity venture when they contribute equity to a new, independent entity. The required cooperation level is high because the participants must contribute cash, technology, people, equipment, or a combination of them to the new company. Ownership is usually commensurate with the value of assets contributed. All of the R&D consortia that we present in Appendix B are equity ventures. NUMMI is an equity joint venture owned equally by General Motors and Toyota. Tax and liability considerations frequently lead companies to choose the equity venture approach. Companies have the flexibility to establish new corporations and partnerships as for-profit or not-for-profit entities. Several research consortia, including the NCMS and the SRC, are organized as tax-exempt corporations under Section 501(c) of the Internal Revenue Code.

OTHER CHARACTERISTICS OF COOPERATIVE VENTURES

Duration of Venture

Cooperative ventures can be labeled "tactical" or "strategic." Tactical ventures are formed for short duration, usually the development of one product or the completion of one project. Strategic ventures have broader goals and often last for an indefinite period. A DoD competitive teaming arrangement (discussed further in Chapter 4) in which two major contractors might cooperate in developing a new weapon system is a tactical venture. In that case, cooperation would probably cease when the weapon system goes into production. On the other hand, a VAP that streamlines operations and improves quality on an ongoing basis is a strategic venture. The semiconductor and metalworking consortia we studied are R&D strategic ventures. CAM-I's broad objective is representative of this group: CAM-I seeks to provide a forum for members to share experiences, test ideas, and pool resources to gain a mutual advantage over nonmember competitors.

Size of Participating Companies

We expected small businesses to be strongly motivated to join consortia.[11] Of the factors discussed above, all (except perhaps global competition) apply to small as

[11] We arbitrarily define a small business to be one with less than $1 billion per year in sales

well as big business. Small businesses would seem to have much to gain from leveraging costs and access and much to lose by assuming too much risk on their own.

We observed, however, that small businesses do not participate in consortia to the extent that larger businesses do. Each of the three semiconductor consortia whose case studies we present in Appendix B is composed of companies with average annual sales of more than $10 billion. The average R&D budget for each of those firms is over $600 million. Of all the consortia we examined, only the NCMS has significant participation by small firms.

Several reasons may account for the lack of participation of small business. Small firms may avoid cooperative ventures because of an independent spirit. They are understandably uneasy when an outsider, particularly a competitor, has access to their "inside" people and facilities. The antitrust laws are intimidating; many businessmen are trained to avoid, at all costs, any contact with competitors. Small businesses may also be unaware of the potential benefits of cooperation. To help, the Department of Commerce is promoting a type of small business cooperative venture called the flexible manufacturing network (FMN). The FMN concept combines characteristics of college research and vocational training with production facilities that are shared by small manufacturers in a regional area. Finally, small businesses are necessarily lean organizations. They may not have adequate staff to handle the many legal, planning, and operational tasks of managing a cooperative venture and they may not have the experts to exploit technical opportunities.

Relationship of Participants

When cooperation is along the value-added chain, the relationship of the participants is said to be "vertical." When a venture is formed among companies that otherwise directly compete, the relationship is termed "horizontal." The antitrust laws have generally prohibited horizontal ventures but have not prevented them totally. As we discuss in Chapter 4, these ventures seem to be gaining corporate and Government acceptability.

EXAMPLES AND OBSERVATIONS

The patterns we have described are useful for classifying consortia. Table 3-1 shows some cooperative ventures classified by their activities and structures. We briefly describe these ventures in Appendix A; in Appendix B we present more

detailed case studies of the preproduction, equity ventures. Although our examples are not intended to be a statistical sampling, we make the following additional observations about consortia activities and structures:

- The equity venture is the structure of choice. Most equity ventures are broad relationships of relatively long or unspecified duration.
- Companies favor contractual ventures for tactical relationships, i.e., those established for a limited time or purpose.
- Although many informal relationships and minority holdings exist in industry, we observed few that would rate as cooperative ventures.
- Vertically oriented ventures are usually structured as contractual ventures or are informal. That structure reflects a natural extension of the traditional "arm's length" relationship between suppliers and customers.

TABLE 3-1

SOME EXAMPLES OF COOPERATIVE VENTURES GROUPED BY THEIR MAJOR ACTIVITY AND STRUCTURE

Activity	Structure			
	Informal	**Minority holding**	**Contractual venture**	**Equity venture**
Preproduction			Chevron Chemical Product Development Partnerships Genentech/Eli Lilly Motorola/Toshiba Texas Instruments/ Hitachi	CAM-I MCC NCMS SEMATECH SRC
Production	Dow Chemical Supplier Partnerships			Diamond-Star Motors NUMMI
Postproduction		Ford/Mazda[a]	Abbott/3M	Dow Elanco[a] GMF Robotics[a] Johnson & Johnson-Merck Consumer Pharmaceuticals[a] Powerex[a]

[a] Also performs preproduction and production activities

MEASURING THE SUCCESS OF CONSORTIA

Because consortia can take so many forms and have so many functions, no single measure of success or "common denominator" can be applied uniformly to each. Such traditional financial measures as sales, market share, and return on investment may be applied to some ventures with the same strengths and weaknesses as when applied to individual firms. If the venture operates as an independent business, these measures are appropriate.

Many joint ventures are established to perform a subset of business functions. These efforts can be measured in much the same way as companies measure their internal functions. R&D consortia, for example, improve design, process, quality, or performance. Comparing these results with starting conditions, stated goals, and time and resources consumed will yield a qualitative measure of success.

Strategic ventures, i.e., those with broad objectives, are particularly difficult to evaluate. Their technical progress can be tracked, but their broad business goals sometimes cannot. For example, we can follow the CAD developments at CAM-I and the circuit line widths achieved by SEMATECH. As we discuss in Appendix B, the strategic R&D consortia we studied have made some progress toward technical goals. We cannot necessarily establish, however, that the technical achievements of a consortium cause changes to the competitiveness (as reflected by market share) of the consortium's members, nor may it be fair to do so. Many economic factors outside the consortium's range of influence, such as exchange rates, the cost of capital, and the members' internal operating efficiencies, also affect competitiveness.

SUMMARY

Many types of consortia are available, but upon examination, we see patterns in industrial cooperation. Companies cooperate to share risks and costs, to fight global competition, to access resources, and to streamline operations. Cooperative activities range from R&D to production, distribution, and marketing. Most consortia are organized as equity or contractual ventures.

We can also describe cooperative ventures by their duration and the relationship of participants. "Strategic" ventures are long ones that have broad objectives; "tactical" ventures are short term and have specific objectives. "Vertical"

relationships involve suppliers and customers; "horizontal" relationships involve competitors.

It is difficult to measure the success of cooperative ventures, especially strategic ones. The technical progress of a consortium can be assessed but cannot be easily linked to broad measures of competitiveness, such as the market share attained by member companies.

CHAPTER 4

LAWS AND PUBLIC POLICIES AFFECTING CONSORTIA

INTRODUCTION

A significant part of a nation's industrial policy is the combination of all relevant laws and public policies that influence industry. Another, narrower definition that is sometimes used equates industrial policy only with direct Government subsidies granted to industry. In this chapter, we follow the broad definition and examine the full range of Government actions that affect consortia. Government policy toward consortia, then, is one element of overall industrial policy.

Even though the United States is regarded as having one of the world's most open marketplaces, the Government is deeply involved in business affairs. As industry responds to changes in the business environment, changes to business-related laws and policies may become necessary. The Government affects consortia in the following ways:

- By antitrust laws
- By Government acquisition strategies
- By direct financial support
- By tax laws
- By trade laws and policies.

Antitrust and tax laws are general in that they affect all industries relatively equally and any financial incentives they offer are available to all.[1] Government acquisition strategies are more specific, influencing cooperation and competition at the program level. Direct financial support and trade policies are industry-specific; they frequently aim to support a specific product or industry. The following sections discuss how consortia are affected by these areas of law and public policy.

[1]The Government can, and does, of course, write specific exemptions or exceptions into otherwise general laws.

ANTITRUST LAWS

Introduction

Antitrust law is the most significant area of Government legislation affecting industrial cooperative activity. Our antitrust laws dictate how and to what degree businesses can cooperate. They affect every step of industrial cooperation from seeking partners to organizing and operating a venture. Congress established the original antitrust laws in 1890 to foster domestic competition and to protect consumers and small businesses from large, market-controlling corporations. Subsequent acts, including the NCRA, and bills now pending are a response to changes in the business environment. The new business environment is characterized by global markets, expensive technology, and the presence of large, vertically integrated foreign competitors. The trend in antitrust legislation is to maintain the spirit of earlier laws and at the same time to reflect the changing perceptions of the procompetitive and anticompetitive effects of cooperative activity.

Basic Antitrust Laws

The basic Federal antitrust laws are the Sherman Act, the Clayton Act, and the Federal Trade Commission Act. The Webb-Pomerene Act and the NCRA are recent revisions to those basic statutes. Title 15 of the United States Code (U.S.C.) codifies the antitrust laws. In addition to the Federal laws described here, most states have similar antitrust statutes.

The Sherman Act (15 U.S.C. 1-7) of 1890 prohibits restraints of trade and acts of monopolization or attempts to monopolize. It is enforced by the Antitrust Division of the Department of Justice. Conviction of criminal violation of the Act can result in a fine of $1 million for corporations and individuals can be sentenced to 3 years in prison and fined $100,000 per violation. Furthermore, conviction on civil charges can result in a penalty of treble damages.

Under the terms of the Clayton Act (15 U.S.C. 12 et seq.), passed in 1914, competitors with a combined market share sufficient to substantially affect price competition may not join in a merger or otherwise collaborate. The Act also prohibits the following specific activities:

- Price discrimination

- Sales on condition of exclusive purchase
- Certain acquisitions of assets
- Use of interlocking directorates.

Conviction under the Clayton Act can result in treble damages.

The Federal Trade Commission Act (15 U.S.C. 41 et seq.) of 1914 prohibits unfair methods of competition and unfair or deceptive practices in interstate and foreign commerce. The Act empowers the Federal Trade Commission to prevent such unfair or deceptive practices. Penalties include a cease-and-desist order and civil fines of up to $10,000 a day for continued violations.

The Webb-Pomerene Act of 1982 (15 U.S.C. 61-65) grants limited antitrust immunity to otherwise potentially illegal activities involving price-fixing and market sharing if the sole purpose of the activities is export trade. According to the Act, these activities, however, must not harm domestic companies, restrict domestic commerce, or include restrictive arrangements with foreign competitors. Further, the law requires all export associations to register their activities with the Federal Trade Commission.

The expense of defending against antitrust suits and the severity of conviction for antitrust violations have led many businesses to develop conservative policies regarding contact with other firms. Particularly among competitors, contact is minimal and usually through the safety net of antitrust attorneys. The prevailing attitude has been that if there is no contact, there can be no charge of collusive activity. This philosophy has effectively minimized the business contacts, once associated only with the restraint of trade, that are also necessary to spawn cooperative ventures.

The National Cooperative Research Act of 1984

The NCRA (15 U.S.C. 4301-4305) encourages R&D consortia. It defines a "joint R&D venture" as one that

- Performs theoretical analysis
- Develops basic engineering techniques

- Extends findings to practical application for demonstration purposes
- Collects and exchanges research information.

The NCRA removes two barriers to cooperation imposed by the basic antitrust laws. First, it states that R&D ventures, if challenged by an antitrust suit, will not be deemed illegal *per se*; rather, they will be judged on all relevant factors affecting competition, the so-called "rule of reason." Second, if convicted, the ventures will be liable for actual damages and costs rather than the treble damages imposed by the Sherman and Clayton Acts.

The NCRA does not abandon the spirit of the original antitrust laws. Whereas the original laws view almost all cooperative ventures as restraint of trade, the NCRA implies that the societal benefits of preproduction joint research may exceed the risk of market-restrictive collusion. The NCRA, however, specifically excludes production and postproduction activities, including

- The exchange among competitors of cost, sales, profitability, price, marketing, or distribution information
- The production of any product, process, or service other than proprietary information developed through the venture.

Furthermore, the NCRA requires that, in order to be protected under the Act, joint research ventures must file written notification of their activities with the Attorney General of the United States and with the Federal Trade Commission.[2] As of March 1989, 245 such notifications had been filed with the Government. Because of multiple filings, these notifications represent about 100 separate consortia. A list of the NCRA registrants is presented in Appendix C.

Antitrust Trends

With the NCRA, Congress enacted what had been the *de facto* policy of the Department of Justice. Before the NCRA, the Department of Justice had never challenged a purely R&D-oriented joint venture.[3] Lawmakers felt, however, that

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[2]Summaries of each filing are printed in the Federal Register. A list of the ventures that have filed is available from the Department of Justice, but details of each notification are not disclosed to the public.

[3]For further discussion, see MacLaren, Terrence F and Walter G. Marple, Jr. *Licensing in Foreign and Domestic Operations – Joint Ventures*. New York: Clark Boardman Company, Ltd., 1987.

joint R&D would help American companies compete in world markets and that, despite the *de facto* policy, the threat of severe penalties under the basic antitrust laws was inhibiting cooperative efforts.

Passage of the NCRA is indicative of a trend of Government antitrust officials in law and in practice to apply the rule of reason over the *per se* rule. Under the Sherman Act, certain types of cooperative agreements are illegal *per se*. That means that once the Government proves collaborative conduct, it need inquire no further into the purpose or economic consequences of the conduct to show a violation of the Act. The rule of reason, on the other hand, means that consortia can use resulting efficiencies as a defense against the charge of diminishing competition. The rule of reason requires an analysis of the purpose and economic consequences of a consortium and a weighing of procompetitive and anticompetitive effects. A typical rule of reason analysis examines

- The size of the venture partners
- The market shares of the partners
- The contributions from the partners and the benefits derived by them
- The likelihood of similar business activities in the absence of the venture
- The nature of collateral restraints placed on the partners as a result of the venture.

At least three pending congressional bills would extend the scope of the National Cooperative Research Act. The Joint Manufacturing Opportunities Act of 1989 (H.R. 423, Wyden) would encourage production and postproduction consortia among small businesses. Consortia would have to file with the Government, as under the NCRA but would need no other specific approval. The National Cooperative Innovation and Commercialization Act of 1989 (H.R. 1024, Boucher) would specifically permit activities proscribed by the NCRA: "manufacturing, producing, marketing, distributing, or otherwise commercializing products, processes, or information developed jointly . . . ." Prospective ventures would be subject to Government approval, which would be forthcoming only after an investigation that

would include a market analysis based on the Herfindahl-Hirshmann Index.[4] The Defense Production Act Amendments of 1989 (S. 1379, Dixon) would represent one of the strongest departures from the basic antitrust laws to date. Under that bill, Government-approved preproduction, production, and postproduction consortia could receive immunity from antitrust laws for work related to the defense industrial base.

We cannot estimate how many consortia would be formed if the antitrust laws were further revised to permit joint production and marketing. Also, the competitive effects of the bills are not totally clear. The bills would help relatively small U.S. firms compete against subsidized, vertically integrated foreign giants. On the other hand, if we permit companies to collaborate in research, manufacturing, distribution, and marketing, then on what basis do they compete as individual firms?

GOVERNMENT ACQUISITION STRATEGIES

Background

When the Federal Government, particularly the DoD, buys a unique major system, it must choose an acquisition strategy for its development and production phases. A fundamental objective of Government acquisition is *competition*. The Government prefers full and open competition, where all qualified contractors are allowed to compete. For many defense products, a well-developed vendor base supports full competition; for others, though, the number of competitors is limited, and DoD may have only a single source.[5]

When a new weapons program is initiated, several contractors typically submit competing design proposals. The DoD then selects proposals for further development through one or more competitive rounds. Generally, DoD selects a single winner of this design competition on the basis of such factors as technical performance and cost. In this case, the Government enjoys a vigorous competitive environment during the development phase, but is left with a single source for the much more expensive production phase.

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[4]The Herfindahl-Hirshmann Index is equal to the sum of the squares of all competitors' market shares in the relevant market. The lower the index, the more competitive the market. The competitive effects of a consortium can be measured by comparing the preconsortium index to the expected postconsortium value.

[5]For a general discussion of Government acquisition, see Kratz, L. A., J. W. Drinnon, and J. R. Hiller. *Establishing Competitive Production Sources: A Handbook for Program Managers*. Prepared for the Defense Systems Management College by ANADAC, INC., Aug 1984.

Establishing Competition in Production

Once the Government has selected a system for production, it has effectively created a single source. Only the original development contractor has the technical data, personnel, tooling, and other critical resources necessary to produce the system. Therefore, if the Government wants to establish a competitor, it must find an effective way to transfer to one or more competing contractors the production technology that it owns by virtue of having funded the R&D.

Several different methods are available for transferring production technology. Two relatively simple approaches are known as "form-fit-function" and "technical data package." In the form-fit-function method, the Government encourages a competing contractor to design an effective substitute for the original product. The technical data package method, on the other hand, requires the original developer to provide a complete package of technical information such that a competent second source can produce an item virtually identical to the original product. The form-fit-function and technical data package methods of technology transfer do not require cooperation or direct interaction between contractors. These two have been used successfully in establishing production competition for relatively simple items. However, they are generally not effective in transferring production technology for complex, expensive items such as, for example, air-to-air missiles.

Cooperation as a Prerequisite to Competition

In an attempt to establish competition in the production of complex systems, the Government has found it necessary to require a certain amount of cooperation among various contractors. Complex technology simply cannot be transferred effectively without cooperation and communication. Two strategies the Government has used frequently within the past 10 years are known as "leader-follower" and "contractor teaming."

Both leader-follower and contractor teaming require significant cooperation between two or more contractors.[6] The purpose of the cooperation is to ensure that each of the contractors has the ability to produce the complete system. In theory, once each of the contractors establishes full production capability, they terminate

[6]Neither arrangement, however, is granted any special immunity or exemption from the antitrust laws.

their cooperative relationship and begin competing for a fraction of the Government's order.

The Leader-Follower Approach

The leader-follower method of establishing a second production source involves direct contractor-to-contractor transfer of production capability.[7] Rather than simply handing over a data package, the original developer (the leader) must actively instruct the prospective competitor (the follower) in all aspects of the production process. Once the follower has demonstrated the capability to produce the item, the leader-follower relationship is terminated and dual source competition begins.

The leader-follower method has generated production competition on a variety of major defense programs, including the Tomahawk cruise missile (General Dynamics/McDonnell Douglas) and the Maverick missile (Hughes/Raytheon).

The Competitive Contractor Teaming Approach

"Competitive contractor teaming" is a unique acquisition strategy, one that must be distinguished from the more common form of "cooperative contractor teaming."[8] In cooperative teaming arrangements, contractors voluntarily form teams with other contractors who have complementary technical skills, i.e., an airframe contractor, an engine contractor, and a radar contractor might form a team. These cooperative teams work together in the development phase and throughout the production phase.

In competitive teaming, however, the Government requires that contractors form teams and that multiple teams compete during the design phase of the program. The contractor teams submit proposals, and the Government evaluates them and ultimately selects a single design for full-scale development and eventual production.

During full-scale development, the winning contractor team completes the design and shares the production information so that soon after completion of the development phase, both members of the team will be able to produce the complete

[7]The leader-follower strategy is outlined in the Federal Acquisition Regulation, Subpart 17.4, *Leader Company Contracting*.

[8]The cooperative contractor teaming strategy is outlined in the Federal Acquisition Regulation, Subpart 9.6, *Contractor Team Arrangements*. The competitive teaming approach is presented in Secretary of the Navy Instruction 4210.6.

system. Once production capability is established by both members, the team relationship is terminated and dual source production competition begins.

Contractor teaming has considerable theoretical appeal and is the Navy's preferred strategy when contracting for the development of new major weapon systems. Several programs currently employ teaming, including the Airborne Self-Protection Jammer (Westinghouse/ITT), the V-22 Osprey (Bell Helicopter/Boeing), and the LHX helicopter (Boeing/Sikorsky, McDonnell Douglas/Bell Helicopter). In none of these programs, however, has the contractor team actually been split into individual competitive producers. One of the oldest teams, Westinghouse/ITT, has been cooperating on the Airborne Self-Protection Jammer since 1978. Therefore, despite its theoretical appeal, the success of the contractor teaming approach in producing more competition has yet to be proven.

These strategies sometimes produce strange relationships. McDonnell Douglas and General Dynamics are cooperating on the development of the Navy's A-12 aircraft, but are on opposing contractor teams vying for the Air Force's Advanced Tactical Fighter (ATF). Hughes and Raytheon cooperate on the Advanced Air-to-Air Missile (AAAM) but compete on the Advanced Medium Range Air-to-Air Missile (AMRAAM). Teaming critics claim these conflicts reduce the level of technology applied to defense products. "You are only going to turn over [information] if it enhances the probability of your winning the production buy, because that is what you are in business for. Other than that, you are going to keep it very close."[9]

Summary

The Government employs acquisition strategies that are appropriate for the markets in which it operates. For simple, commonly used products, normal competitive procedures are appropriate. When faced with a sole-source situation, the Government may use leader-follower and contractor teaming strategies to try to develop competition during production by encouraging cooperation during development. While the leader-follower strategy has created production competition, to date the contractor teaming strategy has not. Contractors who cooperate on one project but compete on a second, similar project may have reduced incentives to openly share their technology with both teams.

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[9]Fred Wood, Executive Vice President, General Dynamics, as quoted in Demers, W. A. "Teaming: Are Two Better Than One?" *Military Forum*, (May 1989): p. 30

DIRECT FINANCIAL SUPPORT

The role of direct Government subsidies to consortia has become one of the most actively debated industrial issues of 1989. Proponents say that domestic industries need direct Government funding to offset the high risks of new technologies, foreign firms' government subsidies, and unfair trade practices. Critics argue that the Government should not be picking industry "winners and losers," that the Government cannot afford direct subsidies, and that the success of direct funding has not been proven.

We found little precedent, in policy or in practice, for the direct financial support of consortia. The Government does finance a large amount of R&D, but most is either specific to a Government need or is "basic research" for the general public good. Government-funded research results becomes public domain information. In 1988, total R&D spending in the United States was $132 billion. Of that amount, the Federal Government contributed $65 billion and about $10 billion of the Government's share went to basic research.[10] Table 4-1 shows a breakdown of the Federal R&D budget by departments and agencies for 1989. State governments also provide direct financial support in the form of grants and special-term loans.

SEMATECH, the semiconductor industry consortium, receives Federal funding of $100 million a year that is expected to continue through 1992 and the NCMS receives about $7 million a year in Federal and state funding. In each of these cases, public funds account for one-half of total revenues. SEMATECH and NCMS are discussed in more detail in Appendix B.

In May 1989 the American Electronics Association (AEA) began lobbying Congress for direct financial support of high-definition television (HDTV). The AEA proposes an HDTV consortium and requests

- $500 million in direct Government loans for U.S. companies developing HDTV
- Government loan guarantees of up to $500 million

[10]Office of Management and Budget. *Special Analyses: Budget of the United States Government, Fiscal Year 1989*, pp. J1, J5.

TABLE 4-1

ESTIMATED 1989 FEDERAL OUTLAYS FOR RESEARCH AND DEVELOPMENT BY DEPARTMENT OR AGENCY

(Dollars in millions)

Department or agency	1989 estimate
Defense	$ 37,023
Health and Human Services	7,446
Energy	5,082
National Aeronautics and Space Administration	4,820
National Science Foundation	1,618
Agriculture	961
Interior	393
Transportation	341
Environmental Protection Agency	335
Commerce	333
Veterans Administration	202
Agency for International Development	198
All other	563
Total	$ 59,315

Source: Office of Management and Budget. *Special Analyses: Budget of the United States Government, Fiscal Year 1989*

- $300 million (over 3 years) in grants for HDTV research, to be administered by the Defense Advanced Research Projects Agency (DARPA)
- $50 million (over 3 years) for HDTV-related work by the Department of Commerce's National Institute of Standards and Technology.[11]

A Congressional bill (H.R. 2287) introduced by U.S. Representative Levine (D., Calif.) would establish an industry HDTV consortium called "TV Tech," provide Federal funding for the consortium, and restrict the resulting technology to

[11]From the written "Testimony of Pat Hill Hubbard, Vice President, American Electronics Association, before the Committee on Commerce, Science, and Transportation, United States Senate, 9 May 1989."

U.S.-owned firms. It would also require that components be manufactured in the United States, to ensure the technology does not migrate to foreign producers.[12]

Despite the above actions, the Government does not appear to have a cohesive policy regarding the direct funding of privately-owned consortia, nor is there a clear public consensus on what that policy should be. Although many American firms are beleaguered by foreign competition and in need of research and investment, the benefits of direct support over broader financial incentives have yet to be proven. It is simply too soon to determine whether the efforts of SEMATECH and NCMS will translate into greater market share and profitability for American companies, and higher value, lower cost products for American consumers.

It is not clear that the industries receiving direct Government funding necessarily need it to prosper. SEMATECH's 14 corporate members have average individual revenues of $11.3 billion (1988 data). Also, they each spend about $878 million (7.8 percent of sales) a year on R&D, and earn profits of $892 million (7.9 percent of sales). If the Government's $100 million contribution to SEMATECH were eliminated, and if the corporations wished to maintain SEMATECH's annual budget of approximately $200 million, each member would have to contribute an additional $7.14 million ($100 million divided by 14 members). Assuming this increase were financed from profits, average corporate profit would decline to about $887 million, a drop of only 0.6 percent.[13] Therefore, each of SEMATECH's members is so financially strong that the Government's contribution to SEMATECH is almost insignificant.

TAX LAWS

The tax laws do not provide specific incentives for companies to conduct business through cooperative ventures. Consortia – equity ventures in particular – are treated the same as individual businesses for tax purposes. In this section, we present some relevant effects of the tax laws on for-profit and not-for-profit consortia.

[12]Separately, DARPA recently awarded $30 million in contracts for defense-related HDTV research.

[13]Financial data from "R&D Scorecard," *Business Week*, (16 Jul 1989): pp. 180 – 232. In computing the change to profit, we assume that R&D expenditures are tax deductible with a marginal Federal income tax rate of 34 percent.

Because these effects are not unique to cooperative ventures, however, we do not discuss them in depth.

The tax effects of for-profit ventures include organizational issues, the investment credit, the research credit, and depreciation. For tax and liability reasons, consortia are often organized as a complex web of corporations and partnerships. The investment tax credit has been eliminated. The research tax credit is a credit of up to 20 percent of the difference between this year's and prior years' research outlays for ventures who increase their research expenditures. It is not a blanket credit for any or all research expenditures.[14] Depreciation is the annual tax deduction for recovering the cost of income-producing property.[15] Government can affect the yearly cash flow of businesses by adjusting recovery periods and depreciation methods. Shorter recovery periods and accelerated depreciation methods defer taxes and can be, in effect, a form of Government incentive.

Several R&D consortia are nonprofit corporations. Section 501(c)(3) of the Internal Revenue Code provides the guidelines for attaining tax-exempt status. The following are the specific requirements to qualify as a 501(c)(3) organization:

- No part of the organization's earnings may be passed to the individual shareholders.
- The venture may neither issue propaganda nor influence legislation.
- The venture may not issue commercial-type insurance.
- The venture must be organized and operated for religious, charitable, scientific, educational, or other public interests.[16]

Should the Government decide to provide specific tax incentives for consortia, any of the above concepts could be utilized. Consortia might be granted special investment or research credits. Certain types of consortia might be granted tax-exempt status for a limited period of time provided they reinvest profits. In contrast to direct financial support of consortia, measures such as these would provide

[14]Morris, Joseph M. *Joint Ventures: An Accounting, Tax, and Administrative Guide*. New York: John Wiley and Sons, 1987, pp. 217 – 218.

[15]U.S. Internal Revenue Service, Publication 534: *Depreciation* (Washington, D.C.: U.S. Government Printing Office, 1988), p. 1.

[16]*Federal Tax Guide*. Chicago: Commerce Clearing House, Inc., 1988, p. 1645

incentives to all businesses who felt they could increase their competitiveness by cooperative efforts.

TRADE LAWS AND POLICIES

The Government can revert to trade restrictions to reduce unfair foreign competition and to protect distressed domestic industries. Tariffs and import quotas are two forms of widely-used import restrictions. Starting in 1981, "voluntary restraint agreements," forms of import quotas, were negotiated with the Japanese; in those agreements, Japanese automobile makers agreed to limit the number of cars they shipped to the United States. That restriction led the Japanese to investigate building cars in the United States. Toyota formed a joint venture, NUMMI, with General Motors to see if it could build cars of adequate quality using American labor. Toyota effectively skirts the import quotas by importing components rather than finished automobiles; Japanese suppliers are the sources of 1,450 out of 1,850 part numbers at NUMMI.[17] Other major Japanese automakers, including Nissan, Honda, and Mazda, have reacted in a similar way to the voluntary restraint agreements.

A recent law, the Omnibus Trade and Competitiveness Act of 1988 (50 U.S.C. 2170), gives the President power to block foreign controlling interest of domestic firms if national security would be threatened. A related form of trade restriction that has not been employed by the United States is the domestic ownership requirement. Historically, foreigners establishing businesses here have been allowed 100 percent ownership (except in certain national security-related cases such as airlines). If the Government were to mandate domestic ownership in businesses (to whatever degree), a rash of joint venture activity would probably take place. Many American multinational companies operate in developing countries that have domestic ownership requirements and in these countries, the American companies have been forced into joint ventures with local partners.

Trade restrictions encourage foreign manufacturers to establish operations in the United States and to enter joint ventures with U.S. firms. Although the trade restrictions are usually intended to "protect" a specific domestic industry, the effect is reduced or eliminated as foreign producers use domestic ventures to circumvent the restrictions.

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[17]Berry, Bryan H. "What Makes the NUMMI Plant Different." *Iron Age.* (5 Sep 1986) p. 32.

SUMMARY

The Government's "industrial policy" toward consortia is defined in laws and public policies. The antitrust laws and the tax laws provide more or less equal incentives to all businesses; the market then determines success and failure. Specific Government actions, such as direct financial assistance and trade policy, focus on a given sector, industry, or business. Those actions may be appropriate if market forces are in conflict with national interest. In governing consortia, public authorities must examine the full range of actions available to them and decide the proper mix of general and specific actions.

BIBLIOGRAPHY

Berg, Sanford V., Jerome Duncan, and Philip Friedman. *Joint Venture Strategies and Corporate Innovation.* Cambridge, Mass.: Oelgeschlager, Gunn, & Hain, Publishers, Inc., 1982.

Berry, Bryan H. "What Makes the NUMMI Plant Different." *Iron Age.* (5 Sep 1986): pp. 27 – 34.

Brandt, Richard and Otis Port. "Silicon Valley Unfurls a Flag: 'Don't Tread on Me'." *Business Week.* (31 Aug 1987): pp. 62 – 63.

Bresnahan, Timothy F. "Quantifying the Competitive Effects of Production Joint Ventures." *International Journal of Industrial Organization.* 4 (1986): pp. 155 – 175.

Business Finance. Vol. 4, No. 4 (Jul/Aug 1989): p. 2.

Carbaugh, Robert and Darwin Wassink. "Joint Ventures, Voluntary Export Quotas, and Domestic Content Requirements." *Quarterly Journal of Business and Economics.* 24 (Spring 1985): pp. 21 – 36.

Cornell, Jon. "Why Sematech is the Only Choice U.S. Chip Makers Have." *Electronic Business.* (1 Jun 1988): pp. 11 – 13.

Cromley, Robert G. and Milford B. Green. "Joint Venture Activity Patterns of U.S. Firms, 1972 – 1979." *Growth and Change.* 16 (Jul 1985): pp. 40 – 53.

Dallmeyer, Dorinda G. "National Security and the Semiconductor Industry." *Technology Review.* (Nov/Dec 1987): pp. 46 – 55.

Defense Science Board. *The Defense Industrial and Technology Base.* Oct 1988.

Demers, W. A. "Teaming: Are Two Better Than One?" *Military Forum.* (May 1989).

Dertouzos, Michael L., Richard K. Lester, and Robert M. Solow. *Made in America: Regaining the Competitive Edge.* Cambridge, Mass.: The MIT Press, 1989.

Donlan, Thomas G. "Chip Shot: Semiconductor Alliance Must Clear Some Tall Barriers." *Barron's.* (9 Mar 1987): pp. 13, 34.

Dotzler, Fred. "Corporate Partnership: Lifeline for Medical Start-Ups." *Medical Marketing and Media.* (Jun 1988): pp. 86 – 92.

Edström, Anders, Bengt Högberg, and Lars Erik Norbäck. "Alternative Explanations of Interorganizational Cooperation: The Case of Joint Programmes and Joint Ventures in Sweden." *Organization Studies.* Vol. 5, No. 2: pp. 147–168.

Eger, Charles L. "Contractor Team Arrangements under the Antitrust Laws." *Public Law Contract Journal.* 17 (Jun 1988): pp. 595–631.

Emerson, Charles D. "A Transplant Takes Root." *American Machinist.* (Jun 1989): pp. 69–71.

Federal Tax Guide. Chicago: Commerce Clearing House, Inc., 1988.

Gold, Barry Allen. "The American Food Corporation." *Journal of Management Case Studies.* (Winter 1986): pp. 312–326.

Goldbaum, Ellen. "New Alliances Share the Work and the Rewards." *Chemical Week.* (7 Dec 1988): pp. 36–40.

Hall, R. Duane. *The International Joint Venture.* New York: Praeger Publishers, 1984.

Hanan, Mark. *Growth Partnering: How to Manage Strategic Alliances for Mutual Profit.* New York: AMA Membership Publications Division, 1986.

Harrigan, Kathryn Rudie. *Managing for Joint Venture Success.* Lexington, Mass.: D.C. Heath and Company, 1986.

Hladik, Karen J. *International Joint Ventures.* Lexington, Mass.: D.C. Heath and Company, 1985.

"Innovation in America." *Business Week.* (16 Jun 1989).

"International Teaming: A Place for Partnerships." *Aviation Week and Space Technology.* (19 Jun 1989): pp. 101–102.

Johnston, Russell and Paul R. Lawrence. "Beyond Vertical Integration – The Rise of the Value-Adding Partnership." *Harvard Business Review.* (Jul–Aug 1988): pp. 94–104.

Kolodziej, Stan. "U.S. R&D Consortia Growing to Counter Foreign Threat." *Computerworld.* (8 Jul 1987): p. 15

Kratz, L. A., J. W. Drinnon, and J. R. Hiller. *Establishing Competitive Production Sources: A Handbook for Program Managers.* Prepared for the Defense Systems Management College by ANADAC, INC., Aug 1984.

MacDonald, George P. "U.S. Antitrust Law as it Relates to U.S. Joint Research and Development Ventures." *International Journal of Technology Management.* 3 (1988): pp. 123 – 134.

MacLaren, Terrence F. and Walter G. Marple, Jr. *Licensing in Foreign and Domestic Operations – Joint Ventures.* New York: Clark Boardman Company, Ltd., 1987.

Morris, Joseph M. *Joint Ventures: An Accounting, Tax, and Administrative Guide.* New York: John Wiley and Sons, 1987.

Muller, E. J. "The Coming of the Corporate Alliance." *Distribution.* (Aug 1988): pp. 82 – 84.

Murphy, William Joseph. "Cooperative Action to Achieve Competitive Strategic Objectives: A Study of the Microelectronics and Computer Technology Corporation." D.B.A. dissertation, Harvard University, 1987.

Newquist, Harvey. "Circling the Corporate Wagons." *Computerworld.* (31 Aug 1987): p. 19.

Office of Management and Budget. *Special Analyses: Budget of the United States Government, Fiscal Year 1989.*

Ohmae, Kenichi. "The Global Logic of Strategic Alliances." *Harvard Business Review.* (Mar – Apr 1989): pp. 143 – 154.

Olleros, Francisco-Javier, and Roderick J. Macdonald. "Strategic Alliances: Managing Complementarity to Capitalize on Emerging Technologies." *Technovation.* (May 1988): pp. 155 – 176.

Parker, Sybil P., ed. *Dictionary of Scientific and Technical Terms.* New York: McGraw-Hill Book Company, 1989.

Port, Otis. "Bob Noyce Created Silicon Valley. Can He Save It?" *Business Week.* (15 Aug 1988): pp. 76 – 79.

"R&D Scorecard." *Business Week.* (16 Jul 1989): pp. 180 – 232.

Reich, Caroline. "Japanese Philosophy Puts Power in Purchasing Partnerships." *Purchasing World.* (Oct 1987): pp. 78 – 80.

Rice, Valerie, Alden M. Hayashi, and Carol Suby. "Sematech: United We Stand?" *Electronic Business.* (1 May 1988): pp. 30 – 37.

Rosenberg, Jerry. *Dictionary of Business and Management.* New York: John Wiley and Sons, 1978, p. 100.

Schacht, Wendy H. "Cooperative R&D: Federal Efforts to Promote Industrial Competitiveness." Congressional Research Service Issue Brief, 24 Apr 1989.

Semiconductor Industry Association Yearbook and Directory, 1988. Cupertino, Calif.: Semiconductor Industry Association, 1987.

Shevlin, Terry. "Taxes and Off-Balance Sheet Financing: Research and Development Limited Partnerships." *The Accounting Review.* 62 (Jul 1987): pp. 480–508.

Stix, Gary. "At Motorola: New Alliances, New Management." *IEEE Spectrum.* (Jul 1988): pp. 39–43.

Stuckey, John A. *Vertical Integration and Joint Ventures in the Aluminum Industry.* Cambridge, Mass.: Harvard University Press, 1983.

Taub, J. S. "Silicon Chip Makers Object to Cooperative R&D Plan." *Business Marketing.* (Mar 1987): pp. 20–21, 28–29.

U.S. Department of Commerce. *Sematech: Progress and Prospects.* Report of the Advisory Council on Federal Participation in SEMATECH 1989, by Jeffrey L. Mayer.

U.S. Department of Commerce, Bureau of the Census. *Statistical Abstract of the United States: 1989.* (109th Edition).

U.S. Department of Commerce, International Trade Administration. *1989 U.S. Industrial Outlook.*

U.S. Department of Defense. *Report of Defense Science Board Task Force on Defense Semiconductor Dependency.* Feb 1987.

Uttal, Bro. "How Chipmakers Can Survive." *Fortune.* (13 Apr 1987): pp. 89, 92.

Weimer, George, et al. "Strategic Alliances Make Marketing and Manufacturing an International Game." *Computer-Aided Engineering.* (Nov 1988): pp. IM2–IM24.

1988–89 Economic Handbook of the Machine Tool Industry. McLean, Va.: NMTBA, The Association for Manufacturing Technology, 1988.

APPENDIX A

EXAMPLES OF COOPERATIVE VENTURES

EXAMPLES OF COOPERATIVE VENTURES

In this appendix we briefly describe the cooperative ventures shown in Table 3-1 of the main text.

ABBOTT/3M

Abbott and 3M have common customers – hospitals – but do not directly compete. Their corporation involves sharing order entry and distribution functions. 3M benefits from Abbott's expertise in distributing health care products, and Abbot benefits by lower transportation costs through greater volumes.

COMPUTER AIDED MANUFACTURING – INTERNATIONAL

Computer Aided Manufacturing – International is a 90-member consortium performing m[illegible] research, including topics on numerical control, cost manageme[illegible], process planning, and quality assurance (see also Appendix B).

CHEVRON CHEMICAL PRODUCT DEVELOPMENT PARTNERSHIPS

Chevron and polystyrene customers jointly develop custom products. The customers have exclusive purchasing rights for a period of time, after which Chevron can market the products on the open market.

DIAMOND-STAR MOTORS

Diamond-Star is a new equity venture between Mitsubishi and Chrysler. Its operation is expected to be similar to that of the New United Motor Manufacturing Inc. (NUMMI).

DOW CHEMICAL SUPPLIER PARTNERSHIPS

This program seeks to improve the quality of Dow's products by improving the quality of the products Dow purchases. The approach is to move the suppliers of all purchased goods and services through three levels of qualification. "Acceptable" suppliers are urged by Dow to improve quality. True cooperation begins at the next level, the "qualified" level, and culminates at the "preferred" level, at which Dow and

suppliers develop mutual goals and continuous improvement plans. Dow benefits by reducing waste and the participating suppliers benefit by gaining more of Dow's business.

DOW ELANCO

Dow Chemical and Eli Lilly are organizing a new equity venture in the plant science and biotechnology business. The venture will be a freestanding entity, which will be owned 60 percent by Dow and 40 percent by Lilly. The companies are pooling their resources because new biotechnology products typically take 7 years and $40 million to develop.

FORD/MAZDA

Ford owns 25 percent of Mazda. Mazda produces the Ford *Probe* and the two companies jointly market the Ford *Probe* and *Taurus* automobiles in Japan. They are currently codeveloping a replacement for the *Escort.*

GENENTECH/ELI LILLY

In a 1978 agreement, Genentech began developing cloned human insulin. Eli Lilly subsidized the development by paying Genentech up-front licensing fees. After the product was developed in 1983, Eli Lilly received marketing rights.

GMF ROBOTICS

GMF Robotics is an equity venture owned equally by General Motors and Fanuc. It performs R&D, assembly, sales and service of robotic systems.

JOHNSON & JOHNSON - MERCK CONSUMER PHARMACEUTICALS

This new (announced 28 March 1989) equally-owned equity venture will develop and market nonprescription products. Johnson & Johnson will contribute marketing, sales, and distribution expertise where Merck will contribute product candidates, research, and manufacturing capabilities.

MOTOROLA/TOSHIBA

Motorola gets Toshiba's manufacturing technology for 256 Kbit and 4 Mbit dynamic random access memories. Toshiba receives Motorola's model 68000

microprocessor (used in the Apple Macintosh computer) technology and will produce it in a Japanese facility jointly owned with Motorola.

MICROELECTRONICS AND COMPUTER TECHNOLOGY CORPORATION

The Microelectronics and Computer Technology Corporation is a 34-member consortium performing research on computer architecture, computer-aided design, packaging/interconnection, supercomputers, and software (see also Appendix B).

NATIONAL CENTER FOR MANUFACTURING SCIENCES

The National Center for Manufacturing Sciences is an 89-member consortium performing research in manufacturing processes, materials, production equipment, factory control, and technology transfer (see also Appendix B).

NEW UNITED MOTOR MANUFACTURING INC.

NUMMI is an equity venture of General Motors and Toyota. Each company contributes capital and management to the venture, but the venture operates under the Toyota production philosophy.

POWEREX

An equity venture owned equally by General Electric, Westinghouse, and Mitsubishi Electronics America, Powerex designs, manufactures, and sells power transistors, rectifiers, and thyristors.

SEMATECH

SEMATECH (SEmiconductor MAnufacturing TECHnology) is a 14-member consortium performing R&D in semiconductor manufacturing techniques (see also Appendix B).

SEMICONDUCTOR RESEARCH CORPORATION

The Semiconductor Research Corporation is a 30-member consortium that sponsors research in silicon-based semiconductor devices (see also Appendix B).

TEXAS INSTRUMENTS/HITACHI

Texas Instruments and Hitachi are codeveloping 16 Mbit dynamic random access memories, and Texas Instruments might begin producing Hitachi-developed static random access memories.

APPENDIX B

CASE STUDIES OF METALWORKING AND SEMICONDUCTOR CONSORTIA

CASE STUDIES OF METALWORKING AND SEMICONDUCTOR CONSORTIA

INTRODUCTION

This appendix presents case studies of five R&D consortia from two industries. From the metalworking industry we present Computer Aided Manufacturing – International (CAM-I) and the National Center for Manufacturing Sciences (NCMS). From the semiconductor industry we present the Microelectronics and Computer Technology Corporation (MCC), the Semiconductor Research Corporation (SRC), and SEMATECH (SEmiconductor MAnufacturing TECHnology).

The metalworking and semiconductor industries are of interest because they play key roles in the manufacture of commercial and defense products. Recently, the health of both industries has been questioned because U.S. firms have lost domestic and global market share in the face of stiff foreign competition.

We do not intend these cases to be a statistical representation of industrial cooperative ventures. In 1981, the Bureau of Economics of the Federal Trade Commission published its final *Statistical Report on Mergers and Acquisitions*, which included joint venture activity. The report was then discontinued, and we were unable to find a comparable data source.

Our emphasis on R&D consortia stems from the availability of information. The consortia were identified from a Department of Justice filing list and Federal Register notices. Further information was obtained from interviews with industry associations and the consortia themselves.

Data availability aside, the concentration on preproduction R&D consortia has some merit. The research agendas reflect the technologies that, by consensus, are important to the future of the industries. The organization structures show how membership and dues provisions influence who participates. From this information, future research might predict who would cooperate, and in what way, under revised legislation permitting production and postproduction ventures. This legislation has

been proposed, and such analysis might help weigh the procompetitive benefits against the anticompetitive drawbacks.

The case discussions follow. We precede each group of consortia with an overview of the industries in which they operate.

METALWORKING INDUSTRY

Overview

The metalworking industry is actually a number of major groups within the standard industrial classification (SIC) system. The two-digit SIC groups in Table B-1 are those that perform metalworking as some part of their manufacturing process. Because metalworking is involved in such a broad range of manufacturing, we have chosen the machine tool industry as illustrative of the environment in which metalworking consortia have been formed. Machine tools are important because they are used by all metalworking industries to produce a wide variety of products.

TABLE B-1

METALWORKING INDUSTRIES

SIC major group	Description
25	Furniture
33	Primary metals
34	Fabricated metal products
35	Nonelectrical machinery
36	Electrical machinery
37	Transportation equipment
38	Precision instruments
39	Miscellaneous manufacturing

A machine tool is "a stationary power-driven machine for the shaping, cutting, turning, boring, drilling, grinding, or polishing of solid parts, especially metals."[1] The machine tool industry is commonly defined as SIC 3541 (machine tools, metal

[1] Parker, Sybil P. ed. *Dictionary of Scientific and Technical Terms*. New York. McGraw-Hill Book Company, 1989, p. 1123.

cutting) and 3542 (machine tools, metal forming). We do not include ancillary equipment required for using machine tools in our discussion of machine tool production. This equipment includes SIC 3544 (special dies and tools, die sets, jigs and fixtures, and industrial molds) and 3545 (cutting tools, machine tool accessories, and precision measuring devices).

The world machine tool market is $31.3 billion a year. The United States, with a domestic market of $4.0 billion, is the third largest consumer of machine tools, behind the Soviet Union and West Germany. American machine tool production is $2.6 billion, or 8 percent of the world market. Imported machine tools account for 49 percent of the U.S. market.[2]

The U.S. machine tool industry is small. If the entire industry were combined into one firm, it would have been ranked No. 151 on the 1987 Fortune 500. About 500 machine tool companies employ a total of 65,000 workers. In 1982, of the 1,392 machine tool establishments (a company can operate more than one establishment), 937 employed fewer than 20 people.

The U.S. machine tool industry faces fierce foreign competition and has been unprofitable for most of the 1980s. The industry's domestic market share has slipped from 90 percent in 1970 to 51 percent in 1987. During that same period, American machine tool producers' share of the world market fell from 19 percent to 8 percent. While all metalworking industries are not as unhealthy as the machine tool industry, they have cause for concern. Machine tools are the heart of an infrastructure – all metalworking industries suffer if machine tools are too expensive, slow, or unreliable. A high level of machine tool imports means that American metalworkers may not get the latest technology. From General Motors' viewpoint, "If you buy the very best from Japan, it has already been at Toyota for two years."[3] It is in this context that two consortia – CAM-I and NCMS – perform research related to metalworking processes.

[2]Machine tool industry statistics, unless otherwise noted, are for the year 1987, and are taken from the *1988–89 Economic Handbook of the Machine Tool Industry*. McLean, Va.: NMTBA, The Association for Manufacturing Technology, 1988.

[3]Dertouzos, Michael L., Richard K. Lester, and Robert M. Solow. *Made in America: Regaining the Competitive Edge*. Cambridge, Mass.: The MIT Press, 1989, p. 233

Computer Aided Manufacturing – International

Computer Aided Manufacturing – International was formed as a nonprofit corporation in 1972 at the initiative of the aerospace industry. In 1985, it was one of the first organizations to file notification with the Department of Justice under the provisions of the National Cooperative Research Act (NCRA).

Computer Aided Manufacturing – International sponsors R&D in the use of computer systems and software to improve the productivity of industry. It seeks to provide a forum for members to share experiences, test ideas, and pool resources to gain a mutual advantage. Originally focused on metalworking, it has diversified into the fields of electronics and telecommunications.

Membership in CAM-I is open to any person or organization. Its membership comprises manufacturers, suppliers to manufacturers, Government agencies, and universities. It has 71 corporate and Government members and 19 educational members. Because membership is not restricted by nationality, participants are drawn internationally. The bulk of the members is from the United States, Europe, and Japan; that is the most significant organizational difference between CAM-I and the other R&D consortia we studied, which draw membership exclusively from the United States.

Total revenues for 1988 were $3 million. The basic member fee is $15,000. In addition, CAM-I has a program sponsor fee of $15,000 to $30,000 for the specific programs in which a member is interested. Additional charges may be levied for specific projects within each program. The U.S. Air Force, U.S. Navy, and Department of Energy are members of CAM-I and fund at the level of private participants. CAM-I has no other U.S. Government funding.

Computer Aided Manufacturing – International research is done both internally and on a contract basis. Members have the right to utilize the results of CAM-I's research for 3 years, after which the information becomes public. The Advanced Technical Planning Committee develops long-term research strategy and the Standards Committee develops and proposes standards in the interest of members. The research agenda is divided into the following program areas:

- *Numerical Control.* Developing new ways to program the computers that control machine tools.

- *Computer Integrated Enterprise.* Linking business activities by computer.
- *Cost Management.* Changing accounting practices to reflect the shift away from direct labor in manufacturing.
- *Electronics Automation.* Applying new technologies to the design, manufacture, and support of generic electronic assembly.
- *Geometric Modeling.* Achieving more complete, computer-based product designs by evolving from surface modeling to solid and product modeling.
- *Intelligent Manufacturing Management.* Developing a real-time production information and control system.
- *Process Planning.* Using artificial intelligence techniques to develop the logic of transforming designs into production plans (manufacturing engineering), including defining the interfaces to design engineering and the shop floor.
- *Quality Assurance.* Advancing the application of computer technologies for assuring total quality in a computer-integrated manufacturing (CIM) environment.

Given the relatively small size of its annual research budget, CAM-I's results are impressive. Here is a sample of technical progress in each program area:

- Numerical Control (NC)
  - Automated NC processor design (1982)
  - Volume decomposition algorithm (1985)
  - Dimension and tolerance solid modeler (1986)
- Computer Integrated Enterprise
  - Begun in 1988; no major results yet
- Cost Management
  - Conceptual design document (1986)
  - Implementation guide (1988)
- Electronics Automation
  - Guidelines to implementing CIM in electronics (1986)
  - Interface standards to support CIM (1986)

- Geometric Modeling
  - Solid modeling extension of the Initial Graphics Exchange System (1979)
  - Finite element modeling application study (1988)
- Intelligent Manufacturing Management
  - MADEMA (Manufacturing Decision Making) software prototype (1985)
  - Process planning interface specification (1987)
- Process Planning
  - XPS-2, procedural-based process planning software (1987)
  - Links to dimension and tolerance modeler, MADEMA software (1987)
- Quality Assurance
  - Dimensional measuring interface specification (DMIS), (1985)
  - DMIS software (1987)
  - Quality information system model (1987)
  - In-process verification study (1987).

A CAM-I spokesman says that the major challenge facing CAM-I is to make more of a commitment to the integration of technologies. To this end, the consortium is maintaining a 3-year rolling technology plan. Table B-2 lists CAM-I's members.

The National Center for Manufacturing Sciences

The NCMS was formed in 1986 through the joint efforts of the DoD and the National Machine Tool Builders' Association (now called NMTBA, The Association for Manufacturing Technology), the Manufacturing Studies Board, General Motors, and about 20 other manufacturing companies. In 1987, NCMS filed notification with the Department of Justice under the provisions of the NCRA.

The trend of American companies to emphasize product development and marketing over manufacturing provided the impetus for establishing NCMS. Faced with intense foreign competition, American manufacturers have tended to underperform with respect to quality, delivery time, and cost. Government-sponsored cooperative R&D programs in Europe and Japan have further strengthened manufacturing capability in those regions.

TABLE B-2

CAM-I MEMBER LIST

Commercial and Government members			Educational members
Aerospatiale	General Dynamics/Fort Worth Division	Nuovo Pignone	California Polytechnic State University
Alcatel	General Dynamics/Data Systems Division	Oki Electric	Cambridge University
Allied Signal Aerospace	General Electric Company	Parker Hannifin	Cranfield Institute of Technology
Allison Gas Turbine	General Motors Corporation	Peat, Marwick, Main & Company	Dorset Institute of Higher Education
Australian Department of Defense	Grumman Aerospace Corporation	Philips International	Helsinki University of Technology
Avery International	GTE Government Systems	Plessey	Illinois Institute of Technology
Beckman Instruments	Hewlett Packard	Price Waterhouse	Katholieke Universiteit Lerven (CRIF)
Boeing Computer Services	Hitachi	Proctor & Gamble Company	Loughborough University of Technology
Boeing Military Aircraft	Honda	Rockwell International	Massachusetts Institute of Technology
British Aerospace	Honeywell	Sandia National Laboratories	North Carolina State University
Carnation Company	Hughes Aircraft Company	Siemens	Politecnico di Milano
Caterpillar Inc.	IVF Swedish Institute of Production Engineering Research	Structural Dynamics Research Corporation	Purdue University
Coopers & Lybrand	Johnson Controls	Texas Instruments	Royal Institute of Technology
Daimler-Benz	Lockheed Aeronautical Systems Co / Burbank Division	Textron	Technical University of Aachen
Dana Corporation	Lockheed Aeronautical Systems Co./ Georgia Division	TNO Metaalinstituut	Universiteit Fredericiana Karlsruhe
Deere & Company	Lockheed Missiles & Space	U S. Air Force Materials Laboratory	University of Maryland
Deloitte Haskins & Sells	Lucas Engineering Systems	U.S. Department of Energy	University of Massachusetts
Digital Electronic Automation	Management Science America	U S. Navy	University of Southern California
Eastman Kodak Company	Martin Marietta Energy Systems	United Technologies/ Pratt & Whitney	University of Texas at Arlington
Eaton Corporation	McDonnell Douglas Corporation	Valmet Corporation	
Electronic Data Systems	Messerschmitt	Volkswagen	
Ernst & Whinney	Nabisco Brands	Westinghouse Electric Company	
Finmeccanica	Northern Telecom	Williams International	
Fujitsu	Northrop Corporation		

Source: Computer Aided Manufacturing - International

The NCMS's overall goal is to aid member firms in becoming internationally competitive in manufacturing by sponsoring manufacturing research and transferring the results to its members. At NCMS, research is not confined to any one industry, but metalworking firms represent a proportionately large involvement. Since NCMS does not disclose information on individual research projects, technical objectives are not available.

The NCMS is organized as a nonprofit corporation. It does very little research on its own; rather, it contracts for each project with the most appropriate university, institution, or company. Members benefit by licensing the developed technology at a reduced fee and are given 30 months proprietary use before the technology is licensed publicly.

Eighty-nine NCMS members are U.S.-based companies, the majority of whose stock is owned by U.S. citizens. NCMS is considering a proposal to open membership to Canadians as well. Members pay a fee of 0.02 percent of manufacturing-related sales, between a minimum of $2,000 and a maximum of $250,000 a year. In addition, many members contribute substantial "in-kind" services that are not recorded.

The total research budget is between $10 million and $15 million a year. NCMS is publicly supported at the Federal and state levels. The Air Force Manufacturing Technology (MANTECH) program is providing $5 million a year for 3 years. The State of Michigan is providing $2 million a year for 5 years.

NCMS's research agenda is divided into six areas:

- Manufacturing processes and materials
- Production equipment design, analysis, testing, and control
- Manufacturing operations
- Manufacturing data and factory control
- Information and technology transfer
- Strategic issues.

Each area has a committee of NCMS members that creates research ideas. Research proposals are then reviewed by a Technical Review Board and the Board of Directors before being issued as contracts.

An NCMS spokesman indicated that NCMS's research program is too new to list concrete results. He said that it has a particular cross-industry interest in electronic data interchange (EDI). A main concern of NCMS is growing to a size where its research can have an effect on American manufacturing. Table B-3 is a list of the NCMS members.

TABLE B-3

NATIONAL CENTER FOR MANUFACTURING SCIENCES MEMBER LIST

Adept Technology	Haworth	Oracle
Advanced Control	Hougen Manufacturing	Parker-Majestic
Advanced Material Process	Hufcor	Perceptron
Advanced Technology	Hurco	Plainfield Tool and Engineering
Airborn	H.R. Krueger Machine Tool	Prime Technology
Amphion	J.P Industries	Radian Corp.
Aries Technology	Kasper Machine Co.	Recognition Equipment
Ascent Logic	Kinefac	Rockwell International
AT&T	Kingsbury Machine Tool	R&B Machine Tool Co.
Automation Intelligence	Lehr Precision	R.F. Monolithics
Bodine	Len Industries	Savoir
Bresson, Rupp, Lipa & Co.	Litton Industrial Automation	Sheffield
Cincinnati Gilbert Machine Tool	Manuflex	Speedfam
Consilium	Masco Machine	Spitfire Tool and Machine
Control Technology	Master Chemical	Sybase
Cross Co.	Mattison Machine Works	S.E. Huffman
DeVlieg/Sundstrand	Mayday Manufacturing	Taft-Peirce Manufacturing
Digital Equipment Corp.	Measurex Automation Systems	Technology Integration
Dravo Automation Sciences	Mechanical Technology	Teledyne
EFCO Inc.	Medar	Texas Instruments
Electronics.Inc.	Metal Improvement	Transform Logic
Extrude Hone Corp.	Met-Coil Systems	Turchan Enterprises
Fabreeka International	Microfab Technologies	United Technologies
Ford	Modern Engineering Service	Valisys
Gearhart Industries	Moore Special Tool	Vulcan Tool
General Electric	Motorola	Walker Magnetics
General Motors	Murdock Engineering	Warner and Swasey
Gilbert/Commonwealth	M D Larkin	Weldon Machine Tool
Gleason Works	National Machinery	Wizdom Systems
Hardinge Brothers	Newcor Bay City	

Source: National Center for Manufacturing Sciences

SEMICONDUCTOR INDUSTRY

Overview

Semiconductors are solid crystalline materials whose electrical conductivity is strongly temperature dependent and varies between that of a conductor and that of an insulator.[4] The term "semiconductor" is commonly applied to a broad range of electronic products, including discrete devices and integrated circuits, whose basic materials are semiconductors. The semiconductor industry is defined by SIC 3674 (semiconductors and related devices). Electronic systems capabilities are often limited by the characteristics of the semiconductor devices they contain. Semiconductor products are key components in electronic products, including computers, telecommunications equipment, factory automation equipment, radar, and many consumer goods. Table B-4 shows a breakdown of semiconductor end use.

TABLE B-4

SEMICONDUCTOR END USE IN 1986

Market	Percentage of semiconductor use, based on value
Computers	34
Communications	13
Industrial products	16
Consumer products	17
Government	20

Source: Semiconductor Industry Association Yearbook and Directory, 1988

The world semiconductor market is $30 billion a year and is projected to grow to $200 billion a year by the Year 2000.[5] The most recent year for which the Semiconductor Industry Association (SIA) has published detailed data is 1986. In that year, the world market was $26 billion, of which the United States consumed

[4]Parker, Sybil P. ed., op. cit., p. 1698.

[5]Dertouzos, Michael L., op. cit., p. 260. This market does not include chips made for internal consumption by "captive" producers.

$8.5 billion. U.S. production in 1986 was $11.4 billion, or 44 percent of the world market.[6]

The American semiconductor industry is distinguished by two types of firms. Twenty-seven captive producers, such as IBM and AT&T, make semiconductors solely for their internal consumption. They tend to be large companies with integrated product lines. The other type of firm, the merchant producer, makes semiconductors for sale on the open market. These firms tend to be small companies whose entire revenues come from semiconductor sales. The merchant trade is dynamic; market leadership varies, supplier relations are transitory, and employee turnover is about 20 percent a year.[7] In contrast to major Japanese producers, the American merchant producers generally have not integrated by joining forces with their equipment makers or downstream systems firms. The SIA reports about 230 merchant producers, including those foreign firms making semiconductors in the United States.

American semiconductor manufacturers dominated world markets from the 1950s through the 1970s, but have lost considerable ground to the Japanese in the 1980s. Japanese companies' share of the world market grew from 28 percent in 1978 to 50 percent today. In one product line, dynamic random access memories (DRAMs), the Japanese have virtually eliminated American competition. U.S. merchant firms' share of the world DRAM market fell from 90 percent in 1975 to 20 percent in 1988 (the U.S. share is even lower in advanced DRAMs).[8] Although American companies still have a reputation for high-quality, innovative products, a recent report on the semiconductor industry stated the following:

- Five of the 10 largest semiconductor manufacturers are Japanese.
- The Japanese semiconductor market is now larger than the U.S. market.[9]

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[6]Unless otherwise noted, semiconductor industry statistics are from the *Semiconductor Industry Association Yearbook and Directory, 1988*. Cupertino, Calif.: Semiconductor Industry Association, 1987.

[7]Dertouzos, Michael L., op.cit., p. 253.

[8]U.S. Department of Commerce, International Trade Administration. *1989 U.S. Industrial Outlook*, p. 30-3.

[9]Dertouzos, Michael L., op. cit., p. 249. Note, however, that the presence of foreign manufacturers in America and American manufacturers abroad greatly increases the complexity of accurately portraying international trade.

The SIA names unfair Japanese trade practices as a major reason for American loss of market share. The complaint centers on two issues. The first is the lack of U.S. access to Japanese markets. The Japanese government removed formal barriers in 1975, but the U.S. share of the Japanese semiconductor market has remained at about 10 percent because of "informal" barriers. In Europe, where Americans and Japanese both compete as foreigners, the American share is 53 percent and the Japanese share is 10 percent. Thus, argues the SIA, American share in Japan is artificially low. The second issue is Japanese dumping of semiconductors in the United States and other countries. Dumping is the practice of selling products below a certain "foreign market value" in order to capture market share. One Department of Commerce study showed the Japanese were selling erasable programmable read-only memories (EPROMs) at roughly half the cost of production. A series of formal complaints on these two issues by the SIA and its member firms led to U.S. trade sanctions against Japanese semiconductors in 1987.[10]

Recent studies attribute the decline in U.S. semiconductor supremacy to the following factors:

- Investment capital is more expensive in the United States than in Japan.
- Japanese semiconductor firms are part of large conglomerates that can cross-subsidize.
- Japanese companies reinvest twice as much in manufacturing and 10 times as much in R&D as American companies.
- Japanese investors accept lower rates of return than American investors.
- U.S. firms' pride in independence impedes the large-scale cooperative R&D required in the semiconductor industry.[11]

[10]The SIA trade complaints and resulting government actions are described more fully in the *Semiconductor Industry Association Yearbook and Directory, 1988*, op cit., pp 19–22.

[11]Dallmeyer, Dorinda G. "National Security and the Semiconductor Industry." *Technology Review* (Nov/Dec 1987): pp. 48–49. See also U.S. Department of Defense. *Report of the Defense Science Board Task Force on Defense Semiconductor Dependency*. Feb 1987.

Two factors distinguish the semiconductor industry from other manufacturing industries. First, considerable R&D is required to develop competitive products and processes. U.S. semiconductor producers spend more on R&D (over 12 percent of sales) than any other American industry.[12] American investor expectations are short-sighted, particularly among semiconductor industry investors. Second, the typical semiconductor company's ownership turns over every 6 to 9 months, leading investors to greatly discount the benefits of long-term projects.

American semiconductor manufacturers are experiencing a declining share of a growing market. Semiconductor manufacturing is an industry of relatively small companies facing vertically-integrated foreign competition. They are innovative, but the cost of R&D is high. A number of companies in the industry feel that a key to competitiveness lies in cooperative product and process research.[13] The following subsections describe three semiconductor-related R&D consortia: the MCC, the SRC, and SEMATECH. Because those consortia share so many common members, we present a consolidated member list in Table B-5. Note that we have included a fourth consortium, U.S. Memories (USM), in the membership table. That consortium announced in July 1989 that it sought Government approval to perform joint production and marketing of random-access-memory products. In early 1990, however, U.S. Memories was dissolved by its members before beginning any operations.

The Microelectronics and Computer Technology Corporation

The MCC was formed in 1982 at the initiative of William Norris, then of Control Data Corporation. The founders of MCC perceived a major long-term competitive threat from Japanese joint R&D projects, most notably, the "fifth-generation" supercomputer project. They also felt that cooperation was necessary to adequately fund research across the broad spectrum of microelectronics technology. MCC was one of the first consortia to file notification with the Department of Justice under the provisions of the NCRA.

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[12] *Semiconductor Industry Association Yearbook and Directory, 1988*, op. cit., p. 16.

[13] Some small semiconductor firms, however, oppose cooperative ventures because such ventures tend to be dominated by large companies. The Cypress Semiconductor Corporation has been particularly vocal in its opposition to such ventures.

TABLE B-5

SEMICONDUCTOR CONSORTIA MEMBERSHIP LIST

Company	MCC	SRC	SEMATECH	USM
Advanced Micro Devices	R	R	R	R
Allied Signal	A			
Ametek	A			
Apple Computer	A			
Applied Materials		R		
AT&T		R	R	
Boeing	R			
Celerity Computing	A			
Control Data	R	R		
Dell Computer	A			
Digital Equipment	R	R	R	R
DuPont	A	R		
Eastman Kodak	R	R		
Eaton		R		
General Dynamics	A			
General Electric	R	R		
General Motors		R		
Harris	R	R	R	
Hewlett-Packard	R	R	R	R
Honeywell	R	R		
Hughes Aircraft	R			
IBM		R	R	R
Intel		R	R	R
Lockheed	R			
LSI Logic		R	R	R
LTV	A			
Magnavox	A			
Martin Marietta	R			
Micron Technology		R	R	
3M	R			

Note: R = Regular member; A = Associate member, or equivalent

TABLE B-5

SEMICONDUCTOR CONSORTIA MEMBERSHIP LIST (Continued)

Company	MCC	SRC	SEMATECH	USM
Motorola	R	R	R	
National Semiconductor	R	R	R	R
NCR	R	R	R	
Perkin-Elmer		R		
Rockwell International	R	R	R	
Silicon Systems		R		
Sun Microsystems	A			
Symbolics	A			
Texas Instruments		R	R	
Tracor	A			
Union Carbide		R		
Universal Instruments	A			
Varian Associates		R		
Westinghouse Electric	R	R		
Xerox		R		
Bellcore	R			
Power Electric Appliance Center	A			
Software Engineering Institute	A			
MCC		A		
SEMATECH		A		

Note: R = Regular member; A = Associate member, or equivalent.

MCC's overall goals are to develop generic microelectronics technology and development tools and to transfer the results to its members. The research program seeks to make computers, applications, and processes faster, more reliable, with higher quality and lower cost. Research is divided into programs on advanced computer architecture, computer-aided design (CAD), packaging/interconnection, superconductor applications, and software technology. MCC also conducts an exploratory initiatives program that considers additional tasks, such as optical

technology and neural networks. The research programs have the following objectives:

- *Advanced Computer Architectures.* To develop advanced object-oriented computer languages and database structures, with concentration in parallel systems.
- *CAD for Complex Circuits.* To develop CAD programs for circuits that ease access to design information and that eventually support systems comprising 50 million devices.
- *Superconductor Applications.* To investigate applications of newly developed high temperature superconducting materials in microelectronics.
- *Packaging/Interconnection.* To develop new techniques that parallel advances in chip integration and speed since rapid advances in circuit technology have caused many processes for providing power and cooling to become obsolete.
- *Software Technology.* To refine software design to streamline the process between concept and specification and to tie together heterogeneous applications in distributed networks of low-cost, high-performance workstations.

The MCC is an incorporated, for-profit cooperative research venture. It has 19 regular members (shareholders) and 15 associate members. Most of its members are large firms from the computer, semiconductor, and aerospace industries. Table B-6 shows a financial profile of MCC members. Three members who are not commonly associated with the microelectronics industry are 3M, Kodak, and DuPont. At least two large computer companies, AT&T and IBM, are not members. One Government agency, the Defense Advanced Research Projects Agency (DARPA), sponsors MCC work. It funds a computer prototyping system called the Experimental Systems Kit.

Member companies must be substantially owned and controlled by U.S. citizens. Members agree to purchase one share of stock (share price: $1 million) and participate in at least one of MCC's research programs. Participants in each program share the program's annual costs equally. MCC's 1989 budget was approximately $70 million.

TABLE B-6

FINANCIAL PROFILE OF MCC MEMBERS

Average individual	Regular members	Associate members
Sales ($ millions)	10,984	7,510
R&D expenditures		
Value ($ millions)	574	291
Percent of sales	5.2	3.9
Profit		
Value ($ millions)	1,012	538
Percent of sales	9.2	7.2

Source: "R&D Scorecard." *Business Week* (16 Jul 1989): pp. 180 – 232.

Most of MCC's research is done internally by about 450 employees. Its staff is a combination of personnel hired directly and representatives of member companies. In addition, MCC maintains research relations with five universities.

Since its creation in 1982, the consortium has generated the following technical results:

- 84 "technology deliveries"
- 11 patents (50 pending)
- 1,400 technical reports
- 100 technical videotapes.

In 1987, Honeywell and NCR incorporated the PROTEUS expert system tool in a marketable product, thus making the first commercial use of MCC technology. In early 1989, MCC issued its first commercial license. Electro Scientific Industries will market a laser bonding process used in semiconductor chip production.

The main challenge facing MCC is how to transfer the technology it develops to the products of its members. After taking over for B. R. Inman in 1987, Chief Executive Officer Grant Dove has restructured the architecture and packaging programs. The essence of the restructuring is to form core technology units that follow long-term goals and satellite units that concentrate on producing ongoing

results for distribution to members. MCC hopes that this approach will allow members to select research areas that most clearly match their technical requirements.

MCC describes itself as being in a state of adolescence. Its initial worries over the willingness of members to cooperate have diminished and its membership is stable, with new members replacing those who have left (in 1986, three turnovers occurred, in 1987 one, and in 1988 none). As time progresses, however, MCC will be under increasing pressure to deliver products of substantial value. The consortium is also reviewing its long-term goals to reflect changes in the microelectronics market and technology since 1982.

The Semiconductor Research Corporation

The SRC was formed in 1982 by the SIA in response to four factors affecting the microelectronics industry:

- Increasing competition, especially from foreign firms
- A decreasing level of university research in silicon-based semiconductor technology
- A shortage of manpower with relevant skills
- Increasing investments required to be competitive in chip design and production.

In 1985, SRC filed notification with the Department of Justice under the provisions of the NCRA.

Its objectives are to increase generic research in silicon-based integrated circuits and to build the base of manpower skilled in the design and manufacture of those circuits. The 1987 SRC Annual Report presents the following technical goal of the research program: to make possible, by 1994, prototype production of chips with:

- A complexity equivalent to a 256 Mbit DRAM (current technology is on the order of 4 Mbits)
- Functional throughput rates of 5×10^{15} gate-Hertz per square centimeter
- Fewer than 10 failures per billion operating hours
- Costs reduced to 1/500 of 1984 levels.

The SRC is organized as a nonprofit corporation. It contracts all research, performing none itself. In addition to the board of directors and senior staff, a Technical Advisory Board manages the research program and coordinates the distribution of results. A University Advisory Committee represents the academic community's viewpoint.

The SRC has 28 regular members and 2 associate members, SEMATECH and MCC. Member companies must be U.S.-owned and U.S.-based. A financial profile of the regular members is shown in Table B-7. An annual membership fee related to the firm's semiconductor sales or usage is required. In 1989, fees ranged from $65,000 to $2.5 million, but no single firm's fee is permitted to exceed 15 percent of SRC's revenues.

TABLE B-7

FINANCIAL PROFILE OF SRC MEMBERS

Average individual	Regular members
Sales ($ millions)	15,412
R&D expenditures	
Value ($ millions)	815
Percent of sales	5.3
Profit	
Value ($ millions)	1,204
Percent of sales	7 8

Source: *"R&D Scorecard" Business Week (16 Jul 1989): pp. 180 - 232*

The SRC's annual revenues are $30 million and of that amount, $10 million is a recent addition from the formation of SEMATECH, whose university research budget is channeled through SRC. SRC overhead consumed about $2.5 million in 1987 and will probably increase with the additional workload for SEMATECH.

The SRC has a memorandum of understanding with the National Science Foundation, which coordinates the participation of the following Federal agencies:

- National Science Foundation

- DoD
- National Security Agency
- National Institute of Standards and Technology
- Defense Nuclear Agency
- Air Force Electronic Technology Laboratory.

The Federal Government provides $2.5 million a year in direct aid to SRC through these agencies. That aid does not include the public portion of the SEMATECH monies administered by SRC (roughly $5 million, since the Government underwrites about half of SEMATECH).

The research program is divided into design, manufacturing, and microstructure. In 1987, SRC awarded 60 research grants to 39 institutions with more than 400 researchers. In 1987, its research resulted in 944 reports, 8 invention disclosures, and 3 patents, and in 1988, it produced 860 new reports, submitted 22 invention disclosures, and applied for 12 patents.

Progress against technical goals has not been summarized, but SRC claims success in expanding its skilled manpower base. In 1982, only 15 of 500 electrical engineers being awarded doctorates had significant training in silicon semiconductor research; by 1988, that number rose to 200 out of 700.

SEMATECH

SEMATECH (SEmiconductor MAnufacturing TECHnology) was formed in March, 1987 in response to recommendations by the Defense Science Board and the SIA.[14] Its chief architect was Charles Sporck, head of National Semiconductor Corporation. The following factors led to SEMATECH's founding:

- *Lack of manufacturing competitiveness.* Japanese advancements in semiconductor manufacturing and quality had offset the U.S. advantage in circuit design. Experts cited a 3 to 5 year lead in Japanese process technology.

[14]The primary source of information for this section is from the U.S. Department of Commerce, *Sematech: Progress and Prospects*, Report of the Advisory Council on Federal Participation in SEMATECH, 1989 by Jeffrey L. Mayer

- *Loss of commodity market share.* American companies were virtually eliminated from the markets of commodity semiconductor products, such as DRAMs. DRAMs account for 15 percent of the total semiconductor market.

- *A need for leveraged R&D.* Compared with their Japanese counterparts, U.S. firms were too small to effectively fund R&D. Many American semiconductor companies averaged about $1 billion in sales, compared to $15 billion for Japanese semiconductor makers.[15] The Japanese had formed vertically integrated giants with links to banks providing "patient capital."

- *National security concern.* Because the U.S. military relies heavily on qualitative advantages to offset the numerical advantages of potential adversaries, any decline in American technological leadership is viewed with concern.

In 1988, SEMATECH filed notification with the Department of Justice under the provisions of the NCRA.

SEMATECH's mission is to develop the manufacturing technology required to return the U.S. semiconductor industry to world competitiveness by the early 1990s. SEMATECH hopes to put the American industry 6 months to 2 years ahead of the foreign competition, and has developed strategic and operating objectives to do so. The strategic objectives are:

- *Develop and transfer manufacturing technology.* Achieve 0.35-micron production technology by 1993, 1 year ahead of the Japanese and 3 years ahead of U.S. firms in SEMATECH's absence.

- *Strengthen the supplier base.* Encourage cooperation between manufacturers and their suppliers through interaction with the Semiconductor Equipment and Materials Institute.

- *Strengthen the technology base.* Sponsor university research through the SRC.

- *Enhance national security.* A strong commercial semiconductor industry will be able to better respond to U.S. military requirements.

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[15] Note, however, that SEMATECH's members had average individual sales of over $10 billion in 1988 (see Table B-8).

SEMATECH's operating objectives form a schedule for achievement of its overall mission:

- *Phase I (1989).* Demonstrate high-yield, factory-scale production of 0.8-micron devices: 4 Mbit DRAMs and 64 Kbit static random access memories (SRAMs).
- *Phase II (1990).* Begin work on factory-scale production of 0.5-micron devices.
- *Phase III (1993).* Achieve overall goal of 0.35-micron production demonstration.

SEMATECH is a nonprofit corporation and performs its own manufacturing research.[16] Premanufacturing research is contracted to universities through the SRC. The founders of SEMATECH contemplated and rejected the idea of using SEMATECH to produce chips for commercial sale. Therefore, it will develop manufacturing technology, and each member will then be responsible for applying that technology to commercial production.

Membership in SEMATECH is shared by 14 U.S. semiconductor manufacturers and the U.S. Government. Membership is open to U.S.-owned and U.S.-based companies. A financial profile of SEMATECH corporate members is shown in Table B-8. The membership fee is 1 percent of the company's semiconductor sales, not to exceed 15 percent of SEMATECH's total industry contributions. The minimum fee is $1 million. A minimum of five engineers must be loaned to SEMATECH, and membership in SRC is required (SRC carries a separate member fee structure that can also reach over $1 million a year).

SEMATECH's total annual revenues are between $200 million and $250 million, of which $10 million is allocated for university research. Federal funding is expected to be $100 million a year for 5 years and state and local funding and in-kind benefits are estimated to total $68 million over the same period. Federal project responsibility lies with DARPA. The Advisory Council on Federal Participation in SEMATECH, chaired by the Under Secretary of Defense (Acquisition), evaluates the Federal role in SEMATECH. Manufacturing research is

[16]Travis County, Texas is contesting SEMATECH's nonprofit status and has levied a $1 million property tax on the consortium. SEMATECH is fighting the assessment.

TABLE B-8

FINANCIAL PROFILE OF SEMATECH MEMBERS

Average individual	Corporate members
Sales ($ millions)	11,278
R&D expenditures	
Value ($ millions)	878
Percent of sales	7.8
Profit	
Value ($ millions)	892
Percent of sales	7.9

Source: "R&D Scorecard." *Business Week*. (16 Jul 1989): pp. 180 – 232.

done in a 200,000 square foot plant in Austin, Tex. SEMATECH employs 700 people, 200 of whom are on loan from member companies.

Because SEMATECH is so young, its results are limited to operation start-up rather than manufacturing innovation. In November 1988, SEMATECH began partial production of current-technology DRAMs and SRAMs contributed by IBM and AT&T.

SEMATECH faces challenges in technology protection, organizational approach, and Government involvement. The first challenge, preventing technology leaks to the competition, raises a number of questions:

- Should member firms be allowed to use the technology in offshore factories or share it with foreign partners?
- What licensing process should be used? Excluding foreign firms might violate the General Agreement on Trade and Tariffs (GATT).
- Should findings be published in journals and presented at professional conferences?
- Should equipment makers that market SEMATECH technology delay selling machinery to foreigners? Some say the converse is happening now.

- What can be done to reduce the high turnover in semiconductor engineers, who tend to take technology with them?

Critic's of SEMATECH's organizational approach contend that the $1 million membership fee (plus the SRC fee) is too high to encourage participation by small firms. They also suggest that the real problem in the American semiconductor industry is the lack of vertical integration and not a lack of manufacturing technology. SEMATECH proponents point to the high leveraging effect, where the fee, in essence, buys access to $250 million in research. Furthermore, they feel that small firms that have traditionally excelled at innovative design should leave manufacturing to bigger companies.

Another challenge in the organizational area is how well SEMATECH will be able to manage its people. Almost one-third of SEMATECH's personnel come from member companies who have been traditionally fiercely competitive. Successfully handling human interaction within SEMATECH and with sponsoring companies could have a profound impact on SEMATECH's innovative success. The high level of Government involvement in SEMATECH could lead to conflicting priorities. SEMATECH's founders expressed concern that the Government would "micro-manage" and steer research away from commercial applications to military ones. Since military demand accounts for only about 10 to 20 percent of U.S. semiconductor sales, an overemphasis on military-only applications, as opposed to commercial or "dual-use" applications, might hinder SEMATECH from achieving its strategic mission of U.S. superiority in the world semiconductor marketplace.

SEMATECH has two major features that distinguish it from most other manufacturing R&D consortia. First, it is concentrating on process development to the point at which it will actually operate a prototype factory. Second, Federal involvement is at a substantial level, both in absolute terms and as a percentage of SEMATECH's budget. SEMATECH's technical results, its quality of intra-industry cooperation, and its cooperation with Government are certain to be closely watched in the coming years.

APPENDIX C

NATIONAL COOPERATIVE RESEARCH ACT OF 1984 REGISTRANTS

NATIONAL COOPERATIVE RESEARCH ACT OF 1984 REGISTRANTS

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE

Number of registrants	Venture name	Federal Register date
1	Exxon Production Research Co. – Halliburton Services	17 Jan 1985
2	Software Productivity Consortium	17 Jan 1985
3	Microelectronics and Computer Technology Corp.	17 Jan 1985
4	Computer Aided Manufacturing – International	24 Jan 1985
5	Bellcore	30 Jan 1985
6	Bethlehem Steel Corp. and U.S. Steel Corp.	30 Jan 1985
7	Semiconductor Research Corp.	30 Jan 1985
8	Center for Advanced Television Studies	1 Feb 1985
9	Eaton Corp. – Fiat Veicoli Industrialia	4 Feb 1985
10	Portland Cement Assoc.	5 Feb 1985
11	Adirondack Lakes Survey Corp.	8 Feb 1985
12	Agrigenetics	8 Feb 1985
13	Empire State Electric Energy Research Corp.	8 Feb 1985
14	MVMA – Acid Rain	8 Feb 1985
15	MVMA – Aerosol Formation in the Atmosphere	8 Feb 1985
16	MVMA – Atmospheric Transformation of...Compounds	8 Feb 1985
17	MVMA – Benzene Emissions	8 Feb 1985
18	MVMA – Combustion Research	8 Feb 1985
19	MVMA – Composition of Diesel Exhaust	8 Feb 1985
20	MVMA – Effects of...Variables on Diesel...Emissions	8 Feb 1985
21	MVMA – Fate of Diesel Particulates in the Atmosphere	8 Feb 1985
22	MVMA – Fate of Polynuclear Aromatic Hydrocarbons...	8 Feb 1985
23	MVMA – Long Range Transport of Air Pollutants	8 Feb 1985
24	MVMA – Motor Fuels Testing	8 Feb 1985
25	MVMA – National Gasoline and Diesel Fuel Survey	8 Feb 1985
26	MVMA – Test Methods for Unregulated Exhaust Emissions	8 Feb 1985
27	MVMA – Truck/Trailer Brake Research	8 Feb 1985

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE (Continued)

Number of registrants	Venture name	Federal Register date
28	MVMA - Vehicle Side Impact Test Procedure	8 Feb 1985
29	Merrell Dow Pharmaceuticals Inc.	19 Feb 1985
30	Uninet Research and Development Co.	1 Mar 1985
31	Bellcore - Honeywell, Inc.	25 Mar 1985
32	United Technologies Corp. - Toshiba Corp.	5 Apr 1985
33	International Partners in Glass Research	10 Apr 1985
34	Portland Cement Assoc.	10 Apr 1985
35	Microelectronics and Computer Technology Corp.	23 Apr 1985
36	Oncogen Ltd.	30 Apr 1985
37	Kaiser Aluminum Corp. and Reynolds Metals Co.	13 May 1985
38	Plastics Recycling Foundation, Inc.	21 May 1985
39	Software Productivity Consortium	21 May 1985
40	Bellcore - Avantek, Inc.	28 Jun 1985
41	Bellcore - Racal Data Communications	28 Jun 1985
42	Bellcore - U.S. Dept. of Army	28 Jun 1985
43	Semiconductor Research Corp.	28 Jun 1985
44	Bellcore - Hertz Institut fuer Nachrichtentechnik	6 Aug 1985
45	Bellcore - ADC Telecommunications, Inc.	5 Sep 1985
46	Portland Cement Assoc.	16 Sep 1985
47	Applied Information Technologies Corp.	9 Oct 1985
48	Plastics Recycling Foundation, Inc.	9 Oct 1985
49	NAHB Research Foundation - Smart House Project	10 Oct 1985
50	Software Productivity Consortium	22 Oct 1985
51	Plough, Inc. - Deet Joint Research Venture	22 Oct 1985
52	Geothermal Drilling Organization	29 Oct 1985
53	Portland Cement Assoc.	15 Nov 1985
54	Pump Research and Development Committee	15 Nov 1985
55	Battelle Memorial Institute - Optoelectronics Group	29 Nov 1985
56	Bellcore - Hitachi, Ltd.	12 Dec 1985
57	Intel Corp. - Xicor Corp.	12 Dec 1985
58	West Va. University Industrial Cooperative Research Center	17 Dec 1985
59	Portland Cement Assoc.	24 Dec 1985

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE (Continued)

Number of registrants	Venture name	Federal Register date
60	Semiconductor Research Corp.	24 Dec 1985
61	Software Productivity Consortium	13 Jan 1986
62	Subsea Production Maintenance...; Brown and Root, Inc.	14 Jan 1986
63	Kean Manufacturing Corp. – Fabristeel Products, Inc.	28 Jan 1986
64	Norton/TRW Ceramics	28 Jan 1986
65	NAHB Research Foundation – Smart House Project	28 Jan 1986
66	Portland Cement Assoc.	4 Feb 1986
67	Southwest Research Institute	18 Feb 1986
68	Computer Aided Manufacturing – International	26 Feb 1986
69	Software Productivity Consortium	11 Mar 1986
70	Portland Cement Assoc.	12 Mar 1986
71	Petroleum Environmental Research Forum	14 Mar 1986
72	Pyrethrin Joint Research Venture	18 Mar 1986
73	Semiconductor Research Corp.	18 Mar 1986
74	KeraMont Research Corp.	3 Apr 1986
75	NAHB Research Foundation – Smart House Project	16 May 1986
76	Petroleum Environmental Research Forum	9 Jun 1986
77	Corp. for Open Systems International	11 Jun 1986
78	Southwest Research Institute	11 Jun 1986
79	Armco, Bethlehem Steel, Inland Steel, and Weirton Steel	12 Jun 1986
80	Petroleum Environmental Research Forum	19 Jun 1986
81	Portland Cement Assoc.	27 Jun 1986
82	International Magnesium Development Corp.	30 Jun 1986
83	Wickes Manufacturing Co.	15 Jul 1986
84	Engine Manufacturers Assoc.	17 Jul 1986
85	Petroleum Environmental Research Forum	17 Jul 1986
86	Portland Cement Assoc.	14 Aug 1986
87	International Magnesium Development Corp.	19 Aug 1986
88	ARCO Chemical Co.	28 Aug 1986
89	NAHB Research Foundation – Smart House Project	28 Aug 1986
90	Corp. for Open Systems International	4 Sep 1986
91	Industry/University Center for Gl ss Research	10 Sep 1986

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE (Continued)

Number of registrants	Venture name	Federal Register date
92	Microelectronics and Computer Technology Corp.	10 Sep 1986
93	Center for Advanced Television Studies	19 Sep 1986
94	Southwest Research Institute	19 Sep 1986
95	Huntington Laboratories, Inc.	7 Oct 1986
96	Corp. for Open Systems International	28 Oct 1986
97	Microelectronics and Computer Technology Corp.	8 Dec 1986
98	Huntington Laboratories, Inc.	16 Dec 1986
99	Babcock and Wilcox Co.	24 Dec 1986
100	International Partners in Glass Research	6 Jan 1987
101	NAHB Research Foundation – Smart House Project	15 Jan 1987
102	Microelectronics and Computer Technology Corp.	3 Feb 1987
103	Portland Cement Assoc.	3 Feb 1987
104	American Cyanamid Co.	5 Feb 1987
105	Software Engineering Research Center	9 Feb 1987
106	Bellcore – Fujitsu	13 Feb 1987
107	Bellcore – Ameritech	13 Feb 1987
108	Corp. for Open Systems International	13 Feb 1987
109	Semiconductor Research Corp.	13 Feb 1987
110	Bellcore – Ameritech (correction)	19 Feb 1987
111	Portland Cement Assoc.	4 Mar 1987
112	National Center for Manufacturing Sciences	17 Mar 1987
113	Industry/University Center for Glass Research	19 Mar 1987
114	Microelectronics and Computer Technology Corp.	19 Mar 1987
115	Petroleum Environmental Research Forum	25 Mar 1987
116	Petroleum Environmental Research Forum	25 Mar 1987
117	Petroleum Environmental Research Forum	25 Mar 1987
118	Metal Casting Technology, Inc.	1 Apr 1987
119	Southwest Research Institute	1 Apr 1987
120	Corp. for Open Systems International	24 Apr 1987
121	Sandvik Special Metals Corp.	24 Apr 1987
122	Bellcore – TriQuint	30 Apr 1987
123	Computer Aided Manufacturing – International	4 May 1987

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE (Continued)

Number of registrants	Venture name	Federal Register date
124	NAHB Research Foundation – Smart House Project	8 May 1987
125	Portland Cement Assoc.	14 May 1987
126	CPW Technology	15 Jun 1987
127	Petroleum Environmental Research Forum	25 Jun 1987
128	Petroleum Environmental Research Forum	25 Jun 1987
129	Pacific Bell – Integrated Network Corp.	1 Jul 1987
130	Portland Cement Assoc.	10 Jul 1987
131	Bellcore – Microwave Semiconductor Corp.	13 Jul 1987
132	Corning Glass Works	15 Jul 1987
133	Corp. for Open Systems International	21 Jul 1987
134	MVMA – Fluorocarbon-134a	30 Jul 1987
135	MVMA – Hose Connections	30 Jul 1987
136	NAHB Research Foundation – Smart House Project	30 Jul 1987
137	Portland Cement Assoc.	26 Aug 1987
138	Southwest Research Institute	26 Aug 1987
139	Material Handling Research Center	11 Sep 1987
140	Southwest Research Institute	18 Sep 1987
141	NAHB Research Foundation – Smart House Project	22 Sep 1987
142	Bellcore – Vitesse Semiconductor Corp.	2 Oct 1987
143	Corp. for Open Systems International	7 Oct 1987
144	Semiconductor Research Corp.	9 Oct 1987
145	Joint Venture of All-Terrain Vehicle Distributors	14 Oct 1987
146	National Forest Products Assoc.	30 Oct 1987
147	Corp. for Open Systems International	9 Nov 1987
148	Portland Cement Assoc.	17 Nov 1987
149	Corp. for Open Systems International	4 Dec 1987
150	Corp. for Open Systems International	15 Dec 1987
151	Software Engineering Research Center	15 Dec 1987
152	Berkeley Sensor and Actuator Center	15 Dec 1987
153	Corp. for Open Systems International	18 Dec 1987
154	Bellcore – NEC	18 Dec 1987
155	NAHB Research Foundation – Smart House Project	5 Jan 1988

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE (Continued)

Number of registrants	Venture name	Federal Register date
156	Composite Materials Characterization, Inc.	15 Jan 1988
157	West Argo, Inc. – Iodophors Joint Venture	15 Jan 1988
158	Southwest Research Institute	19 Jan 1988
159	Microelectronics and Computer Technology Corp.	22 Jan 1988
160	West Argo, Inc. – Iodophors Joint Venture (correction)	12 Feb 1988
161	Petroleum Environmental Research Forum	12 Feb 1988
162	Corp. for Open Systems International	19 Feb 1988
163	Bellcore – NEC	19 Feb 1988
164	Corp. for Open Systems International	8 Mar 1988
165	NAHB Research Foundation – Smart House Project	21 Mar 1988
166	International Energy Program	22 Mar 1988
167	Portland Cement Assoc.	28 Mar 1988
168	Microelectronics and Computer Technology Corp.	29 Mar 1988
169	Bellcore – Sumitomo Electric Industries, Ltd.	6 Apr 1988
170	Engine Manufacturers Assoc.	13 Apr 1988
171	NAHB Research Foundation – Smart House Project	3 May 1988
172	Biotechnology Research and Development Corp.	12 May 1988
173	SEMATECH	19 May 1988
174	Industry/University...Center for Microwave...CAD	31 May 1988
175	International Partners in Glass Research	2 Jun 1988
176	National Center for Manufacturing Sciences	2 Jun 1988
177	Bellcore – Nippon Hoso Kyokai	3 Jun 1988
178	Bellcore – David Sarnoff Research Center	3 Jun 1988
179	Petroleum Environmental Research Forum	3 Jun 1988
180	Industry/University Center for Glass Research	9 Jun 1988
181	West Argo, Inc. – Iodophors Joint Venture	13 Jun 1988
182	Southwest Research Institute	23 Jun 1988
183	Corp. for Open Systems International	30 Jun 1988
184	Institute for Manufacturing and Automation Research	30 Jun 1988
185	International Diatomite Producers Assoc.	14 Jul 1988
186	Manville Corp. – Bird, Inc. Roofing Division Agreement	18 Jul 1988
187	Microelectronics Center of North Carolina	1 Aug 1988

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE (Continued)

Number of registrants	Venture name	Federal Register date
188	Automotive Polymer-Based Composites... Partnership	4 Aug 1988
189	Portland Cement Assoc.	4 Aug 1988
190	National Forest Products Assoc.	4 Aug 1988
191	National Center for Manufacturing Sciences	19 Aug 1988
192	Fabric Softner Quats Joint Venture	19 Aug 1988
193	Dialkyl Project	25 Aug 1988
194	Industry/University...Center for...Mechanical Systems	31 Aug 1988
195	Open Software Foundation, Inc.	7 Sep 1988
196	Cable Television Laboratories, Inc.	7 Sep 1988
197	Bellcore – Landis and Gyr	15 Sep 1988
198	Bellcore – Telettra	15 Sep 1988
199	Portland Cement Assoc.	15 Sep 1988
200	Southwest Research Institute	15 Sep 1988
201	Microelectronics and Computer Technology Corp.	22 Sep 1988
202	Southwest Research Institute	27 Sep 1988
203	Portland Cement Assoc.	28 Sep 1988
204	National Forest Products Assoc.	13 Oct 1988
205	PDES, Inc.	14 Oct 1988
206	Southwest Research Institute	21 Oct 1988
207	Southwest Research Institute	27 Oct 1988
208	Biotechnology Research and Development Corp.	4 Nov 1988
209	Measurement and Control Engineering Center	4 Nov 1988
210	National Center for Manufacturing Sciences	4 Nov 1988
211	Bellcore – GCT	16 Nov 1988
212	Bellcore – Fujitsu	16 Nov 1988
213	X/Open, Ltd.	16 Nov 1988
214	Corp. for Open Systems International	25 Nov 1988
215	Open Software Foundation, Inc.	25 Nov 1988
216	Southwest Research Institute	2 Dec 1988
217	Industrial Consortium for Research and Education	8 Dec 1988
218	NAHB Research Foundation – Smart House Project	8 Dec 1988
219	OSI/Network Management Forum	8 Dec 1988

TABLE C-1

REGISTRANTS LISTED BY FEDERAL REGISTER DATE (Continued)

Number of registrants	Venture name	Federal Register date
220	Cable Television Laboratories, Inc.	16 Dec 1988
221	Petroleum Environmental Research Forum	30 Dec 1988
222	West Argo, Inc. – Iodophors Joint Venture	12 Jan 1989
223	Composite Materials Characterization, Inc.	13 Jan 1989
224	Semiconductor Research Corp.	13 Jan 1989
225	National Center for Manufacturing Sciences	18 Jan 1989
226	OSI/Network Management Forum	26 Jan 1989
227	Industrial Consortium for Research and Education	31 Jan 1989
228	Software Productivity Consortium	31 Jan 1989
229	Computer Aided Manufacturing – International	6 Feb 1989
230	SEMATECH	10 Feb 1989
231	West Argo, Inc. – Iodophors Joint Venture	21 Feb 1989
232	Open Software Foundation, Inc.	23 Feb 1989
233	Portland Cement Assoc.	23 Feb 1989
234	Cable Television Laboratories, Inc.	1 Mar 1989
235	Omega Marine Services International, Inc.	1 Mar 1989
236	Petroleum Environmental Research Forum	1 Mar 1989
237	Southwest Research Institute	1 Mar 1989
238	UNIX International, Inc.	1 Mar 1989
239	B.F. Goodrich Co. – European Vinyls Corp.	10 Mar 1989
240	CAD Framework Initiative, Inc.	13 Mar 1989
241	Semiconductor Research Corp.	13 Mar 1989
242	Southwest Research Institute	13 Mar 1989
243	Portland Cement Assoc.	20 Mar 1989
244	Southwest Research Institute	21 Mar 1989
245	PDES, Inc.	21 Mar 1989

TABLE C-2

REGISTRANTS LISTED ALPHABETICALLY

Venture name	Federal Register date
Adirondack Lakes Survey Corp.	8 Feb 1985
Agrigenetics	8 Feb 1985
American Cyanamid Co.	5 Feb 1987
Applied Information Technologies Corp.	9 Oct 1985
ARCO Chemical Co.	28 Aug 1986
Armco, Bethlehem Steel, Inland Steel, and Weirton Steel	12 Jun 1986
Automotive Polymer-Based Composites... Partnership	4 Aug 1988
Babcock and Wilcox Co.	24 Dec 1986
Battelle Memorial Institute – Optoelectronics Group	29 Nov 1985
Bellcore	30 Jan 1985
Bellcore – ADC Telecommunications, Inc.	5 Sep 1985
Bellcore – Ameritech	13 Feb 1987
Bellcore – Ameritech (correction)	19 Feb 1987
Bellcore – Avantek, Inc.	28 Jun 1985
Bellcore – David Sarnoff Research Center	3 Jun 1988
Bellcore – Fujitsu	13 Feb 1987
Bellcore – Fujitsu	16 Nov 1988
Bellcore – GCT	16 Nov 1988
Bellcore – Hertz Institut fuer Nachrichtentechnik	6 Aug 1985
Bellcore – Hitachi, Ltd.	12 Dec 1985
Bellcore – Honeywell, Inc.	25 Mar 1985
Bellcore – Landis and Gyr	15 Sep 1988
Bellcore – Microwave Semiconductor Corp	13 Jul 1987
Bellcore – NEC	18 Dec 1987
Bellcore – NEC	19 Feb 1988
Bellcore – Nippon Hoso Kyokai	3 Jun 1988
Bellcore – Racal Data Communications	28 Jun 1985
Bellcore – Sumitomo Electric Industries, Ltd.	6 Apr 1988
Bellcore – Telettra	15 Sep 1988
Bellcore – TriQuint	30 Apr 1987
Bellcore – U.S. Dept. of Army	28 Jun 1985
Bellcore – Vitesse Semiconductor Corp.	2 Oct 1987

TABLE C-2

REGISTRANTS LISTED ALPHABETICALLY (Continued)

Venture name	Federal Register date
Berkeley Sensor and Actuator Center	15 Dec 1987
Bethlehem Steel Corp. and U.S. Steel Corp.	30 Jan 1985
Biotechnology Research and Development Corp.	4 Nov 1988
Biotechnology Research and Development Corp.	12 May 1988
B.F. Goodrich Co. – European Vinyls Corp.	10 Mar 1989
Cable Television Laboratories, Inc.	1 Mar 1989
Cable Television Laboratories, Inc.	7 Sep 1988
Cable Television Laboratories, Inc.	16 Dec 1988
CAD Framework Initiative, Inc.	13 Mar 1989
Center for Advanced Television Studies	1 Feb 1985
Center for Advanced Television Studies	19 Sep 1986
Composite Materials Characterization, Inc.	15 Jan 1988
Composite Materials Characterization, Inc.	13 Jan 1989
Computer Aided Manufacturing – International	6 Feb 1989
Computer Aided Manufacturing – International	26 Feb 1986
Computer Aided Manufacturing – International	4 May 1987
Computer Aided Manufacturing – International	24 Jan 1985
Corning Glass Works	15 Jul 1987
Corp. for Open Systems International	24 Apr 1987
Corp. for Open Systems International	7 Oct 1987
Corp. for Open Systems International	21 Jul 1987
Corp. for Open Systems International	4 Sep 1986
Corp. for Open Systems International	11 Jun 1986
Corp. for Open Systems International	13 Feb 1987
Corp. for Open Systems International	28 Oct 1986
Corp. for Open Systems International	8 Mar 1988
Corp. for Open Systems International	19 Feb 1988
Corp. for Open Systems International	25 Nov 1988
Corp. for Open Systems International	30 Jun 1988
Corp. for Open Systems International	4 Dec 1987
Corp. for Open Systems International	9 Nov 1987
Corp. for Open Systems International	18 Dec 1987

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REGISTRANTS LISTED ALPHABETICALLY (Continued)

Venture name	Federal Register date
Corp. for Open Systems International	15 Dec 1987
CPW Technology	15 Jun 1987
Dialkyl Project	25 Aug 1988
Eaton Corp. – Fiat Veicoli Industrialia	4 Feb 1985
Empire State Electric Energy Research Corp.	8 Feb 1985
Engine Manufacturers Assoc.	13 Apr 1988
Engine Manufacturers Assoc.	17 Jul 1986
Exxon Production Research Co. – Halliburton Services	17 Jan 1985
Fabric Softner Quats Joint Venture	19 Aug 1988
Geothermal Drilling Organization	29 Oct 1985
Huntington Laboratories, Inc.	16 Dec 1986
Huntington Laboratories, Inc.	7 Oct 1986
Industrial Consortium for Research and Education	8 Dec 1988
Industrial Consortium for Research and Education	31 Jan 1989
Industry/University Center for Glass Research	10 Sep 1986
Industry/University Center for Glass Research	19 Mar 1987
Industry/University Center for Glass Research	9 Jun 1988
Industry/University...Center for Microwave...CAD	31 May 1988
Industry/University...Center for...Mechanical Systems	31 Aug 1988
Institute for Manufacturing and Automation Research	30 Jun 1988
Intel Corp. – Xicor Corp.	12 Dec 1985
International Diatomite Producers Assoc.	14 Jul 1988
International Energy Program	22 Mar 1988
International Magnesium Development Corp.	30 Jun 1986
International Magnesium Development Corp.	19 Aug 1986
International Partners in Glass Research	10 Apr 1985
International Partners in Glass Research	2 Jun 1988
International Partners in Glass Research	6 Jan 1987
Joint Venture of All-Terrain Vehicle Distributors	14 Oct 1987
Kaiser Aluminum Corp. and Reynolds Metals Co.	13 May 1985
Kean Manufacturing Corp. – Fabristeel Products, Inc.	28 Jan 1986
KeraMont Research Corp.	3 Apr 1986

TABLE C-2

REGISTRANTS LISTED ALPHABETICALLY (Continued)

Venture name	Federal Register date
Manville Corp. – Bird, Inc. Roofing Division Agreement	18 Jul 1988
Material Handling Research Center	11 Sep 1987
Measurement and Control Engineering Center	4 Nov 1988
Merrell Dow Pharmaceuticals Inc.	19 Feb 1985
Metal Casting Technology, Inc.	1 Apr 1987
Microelectronics and Computer Technology Corp.	29 Mar 1988
Microelectronics and Computer Technology Corp.	22 Sep 1988
Microelectronics and Computer Technology Corp.	17 Jan 1985
Microelectronics and Computer Technology Corp.	22 Jan 1988
Microelectronics and Computer Technology Corp.	19 Mar 1987
Microelectronics and Computer Technology Corp.	3 Feb 1987
Microelectronics and Computer Technology Corp.	23 Apr 1985
Microelectronics and Computer Technology Corp.	8 Dec 1986
Microelectronics and Computer Technology Corp.	10 Sep 1986
Microelectronics Center of North Carolina	1 Aug 1988
MVMA – Acid Rain	8 Feb 1985
MVMA – Aerosol Formation in the Atmosphere	8 Feb 1985
MVMA – Atmospheric Transformation of...Compounds	8 Feb 1985
MVMA – Benzene Emissions	8 Feb 1985
MVMA – Combustion Research	8 Feb 1985
MVMA – Composition of Diesel Exhaust	8 Feb 1985
MVMA – Effects of...Variables on Diesel...Emissions	8 Feb 1985
MVMA – Fate of Diesel Particulates in the Atmosphere	8 Feb 1985
MVMA – Fate of Polynuclear Aromatic Hydrocarbons...	8 Feb 1985
MVMA – Fluorocarbon-134a	30 Jul 1987
MVMA – Hose Connections	30 Jul 1987
MVMA – Long Range Transport of Air Pollutants	8 Feb 1985
MVMA – Motor Fuels Testing	8 Feb 1985
MVMA – National Gasoline and Diesel Fuel Survey	8 Feb 1985
MVMA – Test Methods for Unregulated Exhaust Emissions	8 Feb 1985
MVMA – Truck/Trailer Brake Research	8 Feb 1985
MVMA – Vehicle Side Impact Test Procedure	8 Feb 1985

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REGISTRANTS LISTED ALPHABETICALLY (Continued)

Venture name	Federal Register date
NAHB Research Foundation – Smart House Project	30 Jul 1987
NAHB Research Foundation – Smart House Project	21 Mar 1988
NAHB Research Foundation – Smart House Project	3 May 1988
NAHB Research Foundation – Smart House Project	8 Dec 1988
NAHB Research Foundation – Smart House Project	10 Oct 1985
NAHB Research Foundation – Smart House Project	22 Sep 1987
NAHB Research Foundation – Smart House Project	5 Jan 1988
NAHB Research Foundation – Smart House Project	15 Jan 1987
NAHB Research Foundation – Smart House Project	28 Jan 1986
NAHB Research Foundation – Smart House Project	16 May 1986
NAHB Research Foundation – Smart House Project	8 May 1987
NAHB Research Foundation – Smart House Project	28 Aug 1986
National Center for Manufacturing Sciences	17 Mar 1987
National Center for Manufacturing Sciences	2 Jun 1988
National Center for Manufacturing Sciences	4 Nov 1988
National Center for Manufacturing Sciences	19 Aug 1988
National Center for Manufacturing Sciences	18 Jan 1989
National Forest Products Assoc.	4 Aug 1988
National Forest Products Assoc.	13 Oct 1988
National Forest Products Assoc.	30 Oct 1987
Norton/TRW Ceramics	28 Jan 1986
Omega Marine Services International, Inc.	1 Mar 1989
Oncogen Ltd.	30 Apr 1985
Open Software Foundation, Inc.	25 Nov 1988
Open Software Foundation, Inc.	7 Sep 1988
Open Software Foundation, Inc.	23 Feb 1989
OSI/Network Management Forum	26 Jan 1989
OSI/Network Management Forum	8 Dec 1988
Pacific Bell – Integrated Network Corp.	1 Jul 1987
PDES, Inc.	21 Mar 1989
PDES, Inc.	14 Oct 1988
Petroleum Environmental Research Forum	3 Jun 1988

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REGISTRANTS LISTED ALPHABETICALLY (Continued)

Venture name	Federal Register date
Petroleum Environmental Research Forum	25 Jun 1987
Petroleum Environmental Research Forum	14 Mar 1986
Petroleum Environmental Research Forum	30 Dec 1988
Petroleum Environmental Research Forum	1 Mar 1989
Petroleum Environmental Research Forum	17 Jul 1986
Petroleum Environmental Research Forum	19 Jun 1986
Petroleum Environmental Research Forum	9 Jun 1986
Petroleum Environmental Research Forum	25 Mar 1987
Petroleum Environmental Research Forum	25 Mar 1987
Petroleum Environmental Research Forum	25 Mar 1987
Petroleum Environmental Research Forum	25 Jun 1987
Petroleum Environmental Research Forum	12 Feb 1988
Plastics Recycling Foundation, Inc.	21 May 1985
Plastics Recycling Foundation, Inc.	9 Oct 1985
Plough, Inc. – Deet Joint Research Venture	22 Oct 1985
Portland Cement Assoc.	24 Dec 1985
Portland Cement Assoc.	27 Jun 1986
Portland Cement Assoc.	10 Jul 1987
Portland Cement Assoc.	4 Aug 1988
Portland Cement Assoc.	12 Mar 1986
Portland Cement Assoc.	15 Nov 1985
Portland Cement Assoc.	15 Sep 1988
Portland Cement Assoc.	28 Sep 1988
Portland Cement Assoc.	23 Feb 1989
Portland Cement Assoc.	14 May 1987
Portland Cement Assoc.	16 Sep 1985
Portland Cement Assoc.	5 Feb 1985
Portland Cement Assoc.	26 Aug 1987
Portland Cement Assoc.	17 Nov 1987
Portland Cement Assoc.	20 Mar 1989
Portland Cement Assoc.	10 Apr 1985
Portland Cement Assoc.	3 Feb 1987

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REGISTRANTS LISTED ALPHABETICALLY (Continued)

Venture name	Federal Register date
Portland Cement Assoc.	4 Mar 1987
Portland Cement Assoc.	4 Feb 1986
Portland Cement Assoc.	14 Aug 1986
Portland Cement Assoc.	28 Mar 1988
Pump Research and Development Committee	15 Nov 1985
Pyrethrin Joint Research Venture	18 Mar 1986
Sandvik Special Metals Corp.	24 Apr 1987
SEMATECH	10 Feb 1989
SEMATECH	19 May 1988
Semiconductor Research Corp.	13 Feb 1987
Semiconductor Research Corp.	18 Mar 1986
Semiconductor Research Corp.	9 Oct 1987
Semiconductor Research Corp.	13 Mar 1989
Semiconductor Research Corp.	30 Jan 1985
Semiconductor Research Corp.	13 Jan 1989
Semiconductor Research Corp.	28 Jun 1985
Semiconductor Research Corp.	24 Dec 1985
Software Engineering Research Center	9 Feb 1987
Software Engineering Research Center	15 Dec 1987
Software Productivity Consortium	13 Jan 1986
Software Productivity Consortium	17 Jan 1985
Software Productivity Consortium	22 Oct 1985
Software Productivity Consortium	31 Jan 1989
Software Productivity Consortium	11 Mar 1986
Software Productivity Consortium	21 May 1985
Southwest Research Institute	1 Mar 1989
Southwest Research Institute	18 Feb 1986
Southwest Research Institute	13 Mar 1989
Southwest Research Institute	21 Mar 1989
Southwest Research Institute	18 Sep 1987
Southwest Research Institute	15 Sep 1988
Southwest Research Institute	19 Jan 1988

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REGISTRANTS LISTED ALPHABETICALLY (Continued)

Venture name	Federal Register date
Southwest Research Institute	27 Sep 1988
Southwest Research Institute	19 Sep 1986
Southwest Research Institute	23 Jun 1988
Southwest Research Institute	11 Jun 1986
Southwest Research Institute	1 Apr 1987
Southwest Research Institute	2 Dec 1988
Southwest Research Institute	26 Aug 1987
Southwest Research Institute	27 Oct 1988
Southwest Research Institute	21 Oct 1988
Subsea Production Maintenance...; Brown and Root, Inc.	14 Jan 1986
Uninet Research and Development Co.	1 Mar 1985
United Technologies Corp. – Toshiba Corp.	5 Apr 1985
UNIX International, Inc.	1 Mar 1989
West Argo, Inc. – Iodophors Joint Venture	15 Jan 1988
West Argo, Inc. – Iodophors Joint Venture	21 Feb 1989
West Argo, Inc. – Iodophors Joint Venture	13 Jun 1988
West Argo, Inc. – Iodophors Joint Venture	12 Jan 1989
West Argo, Inc. – Iodophors Joint Venture (correction)	12 Feb 1988
West Va. University Industrial Cooperative Research Center	17 Dec 1985
Wickes Manufacturing Co.	15 Jul 1986
X/Open, Ltd.	16 Nov 1988

APPENDIX D

GLOSSARY

GLOSSARY

AEA	=	American Electronics Association
Bellcore	=	Bell Communications Research, Inc.
CAD	=	computer-aided design
CAM-I	=	Computer Aided Manufacturing – International
CIM	=	computer integrated manufacturing
DARPA	=	Defense Advanced Research Projects Agency
DMIS	=	dimensional measuring interface specification
DRAM	=	dynamic random access memory
FMN	=	flexible manufacturing network
HDTV	=	high definition television
MADEMA	=	Manufacturing Decision Making
MCC	=	Microelectronics and Computer Technology Corporation
MIT	=	Massachusetts Institute of Technology
MVMA	=	Motor Vehicle Manufacturers Association
NAHB	=	National Association of Home Builders
NC	=	numerical control
NCMS	=	National Center for Manufacturing Sciences
NCRA	=	National Cooperative Research Act
NMTBA	=	National Machine Tool Builders' Association
NUMMI	=	New United Motor Manufacturing, Inc.
PDES	=	Product Data Exchange S. c. ification
R&D	=	research and development
SEMATECH	=	SEmiconductor MAnufacturing TECHnology

SIA	=	Semiconductor Industry Association
SIC	=	Standard Industrial Classification
SRAM	=	static random access memory
SRC	=	Semiconductor Research Corporation
VAP	=	value-adding partnership
U.S.C.	=	United States Code
USM	=	U.S. Memories